



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>5</sup> : C12N 15/12, C12P 21/02, 21/08 C12N 5/10, 1/21, A61K 37/02 // (C12N 1/21, C12R 1:19)		A1	(11) International Publication Number: <b>WO 92/20798</b>  (43) International Publication Date: 26 November 1992 (26.11.92)
(21) International Application Number: PCT/US92/04295 (22) International Filing Date: 21 May 1992 (21.05.92)  (30) Priority data: 705,256 24 May 1991 (24.05.91) US 765,212 25 September 1991 (25.09.91) US 790,801 8 November 1991 (08.11.91) US 847,743 6 March 1992 (06.03.92) US 880,917 11 May 1992 (11.05.92) US  (71) Applicant: GENENTECH, INC. [US/US]; 460 Point San Bruno Boulevard, South San Francisco, CA 94080 (US). (72) Inventors: VANDLEN, Richard, L. ; 1015 Hayne Road, Hillsborough, CA 94010 (US), HOLMES, William, E. ; 29 Eastlake, Pacifica, CA 94044 (US).		(74) Agents: HENSLEY, Max, D. et al.; Genentech, Inc., 460 Point San Bruno Boulevard, South San Francisco, CA 94080 (US).  (81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), MC (European patent), NL (European patent), SE (European patent).  <b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

(54) Title: HEREGULINS (HRGs), BINDING PROTEINS OF P185<sup>erb2</sup>

HRG2- $\alpha$	221	S H L V K C A E K E K T F C V N G G E C F M V K D L S N P S R Y L C K C Q P G F T G A R C T E N	230	240	250	260
EGF		N S D S E C P L S H D G Y C L H D G V C M Y I E A L - - - D K Y A C N C V V G Y I G E R C Q Y R				
TGF- $\alpha$		N D C P D S H T Q F C F H - G T C R F L V Q E - - - D K P A C V C H S G Y V G A R C E H A				
Amphiregulin		K K K N P C N A E F Q N F C I H - G E C K Y I E H L - - - E A V T C K C Q Q E Y F G E R C G E K				
Schwannoma		K K K N P C A A K F Q N F C I H - G E C R Y I E N L - - - E V V T C H C H Q D Y F G E R C G E K				
HB-EGF		K K R D P C L R K Y K D F C I H - G E C K Y V K E L - - - R A P S C I C H P G Y H G E R C H G L				

HRG2- $\alpha$	270	V P M K V Q N Q E K A E E L Y Q K R V L T I T G I C I A L L V V G I M C V V A Y C K T K K O R .	280	290	300	310
EGF		D L K W W E L R H A G H G Q Q Q - K V I V V A V C V V V L V M L L L S L W G A H Y Y R T Q K				
TGF- $\alpha$		D L L A I V V A A S Q K - - - - - K Q A I T A L V V S I V A L A V L I I T C V L I H C C Q V				
Amphiregulin		S M K T H S M I D S S L S - - - - K I A L A A I A F M S A V I L T A V A V I T V Q L R R O Y				
Schwannoma		T M K T Q K D D S D L S - - - - K I A L A A I I V F V S A V S V A A I G I I T A V L L R K R				
HB-EGF		S L P V E N R L Y T Y D - - - - - H T I L A V V A V V L S S V C L L V I V G L L H F R Y H R				

TRANSMEMBRANE REGION

## (57) Abstract

A novel polypeptide with binding affinity for the p185<sup>HER2</sup> receptor, designated heregulin- $\alpha$ , has been identified and purified from cultured human cells. DNA sequences encoding additional heregulin polypeptides, designated heregulin- $\alpha$ , heregulin- $\beta$ 1, heregulin- $\beta$ 2, and heregulin- $\beta$ 3, have been isolated, sequenced and expressed. Provided herein are nucleic acid sequences encoding the amino acid sequences of heregulins useful in the production of heregulins by recombinant means. Further provided are the amino acid sequences of heregulins and purification methods therefor. Heregulins and their antibodies are useful as therapeutic agents and in diagnostic methods.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	MI	Mali
AU	Australia	FR	France	MN	Mongolia
BB	Barbados	GA	Gabon	MR	Mauritania
BE	Belgium	GB	United Kingdom	MW	Malawi
BF	Burkina Faso	GN	Guinea	NL	Netherlands
BG	Bulgaria	GR	Greece	NO	Norway
BJ	Benin	HU	Hungary	PL	Poland
BR	Brazil	IE	Ireland	RO	Romania
CA	Canada	IT	Italy	RU	Russian Federation
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland	KR	Republic of Korea	SN	Senegal
CI	Côte d'Ivoire	LI	Liechtenstein	SU	Soviet Union
CM	Cameroon	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TC	Togo
DE	Germany	MC	Monaco	US	United States of America
DK	Denmark	MG	Madagascar		
ES	Spain				

HERGULINS (HRGs), BINDING PROTEINS OF P185<sup>erbB2</sup>BACKGROUND OF THE INVENTION

5

Field of the Invention

This invention relates to polypeptide ligands that bind to receptors implicated in cellular growth. In particular, it relates to polypeptide ligands that bind to the p185<sup>HER2</sup> receptor.

10

Description of Background and Related Art

Cellular protooncogenes encode proteins that are thought to regulate normal cellular proliferation and differentiation. Alterations in their structure or amplification of their expression lead to abnormal cellular growth and have been associated with carcinogenesis (Bishop JM, *Science* 235:305-311 [1987]); (Rhims JS, *Cancer Detection and Prevention* 11:139-149 [1988]); (Nowell PC, *Cancer Res.* 46:2203-2207 [1986]); (Nicolson GL, *Cancer Res.* 47:1473-1487 [1987]). Protooncogenes were first identified by either of two approaches. First, molecular characterization of the genomes of transforming retroviruses showed that the genes responsible for the transforming ability of the virus in many cases were altered versions of genes found in the genomes of normal cells. The normal version is the protooncogene, which is altered by mutation to give rise to the oncogene. An example of such a gene pair is represented by the EGF receptor and the v-erb-B gene product. The virally encoded v-erb-B gene product has suffered truncation and other alterations that render it constitutively active and endow it with the ability to induce cellular transformation (Yarden *et al.*, *Ann. Rev. Biochem.* 57:443-478, 1988).

The second method for detecting cellular transforming genes that behave in a dominant fashion involves transfection of cellular DNA from tumor cells of various species into nontransformed target cells of a heterologous species. Most often this was done by transfection of human, avian, or rat DNAs into the murine NIH 3T3 cell line (Bishop JM, *Science* 235:305-311 [1987]); (Rhims JS, *Cancer Detection and Prevention* 11:139-149 [1988]); (Nowell PC, *Cancer. Res.* 46:2203-2207 [1986]); (Nicolson GL, *Cancer. Res.* 47:1473-1487 [1987]); (Yarden *et al.*, *Ann. Rev. Biochem.* 57:443-478 [1988]). Following several cycles of genomic DNA isolation and retransfection, the human or other species DNA was molecularly cloned from the murine background and subsequently characterized. In some cases, the same genes were isolated following transfection and cloning as those identified by the direct characterization of transforming viruses. In other cases, novel oncogenes were identified. An example of a novel oncogene identified by this transfection assay is the *neu* oncogene. It was discovered by Weinberg and colleagues in a transfection experiment in which the initial DNA was derived from a carcinogen-induced rat neuroblastoma (Padhy *et al.*, *Cell* 28:865-871

[1982]]; (Schechter *et al.*, *Nature* 312:513-516 [1984]). Characterization of the rat *neu* oncogene revealed that it had the structure of a growth factor receptor tyrosine kinase, had homology to the EGF receptor, and differed from its normal counterpart, the *neu* protooncogene, by an activating mutation in its transmembrane domain (Bargmann *et al.*, *Cell* 5 45:649-657 [1986]). The human counterpart to *neu* is the HER2 protooncogene, also designated c-erb- B2 (Coussens *et al.*, *Science* 230:1137-1139 [1985]), WO89/06692).

The association of the HER2 protooncogene with cancer was established by yet a third approach, that is, its association with human breast cancer. The HER2 protooncogene was first discovered in cDNA libraries by virtue of its homology with the EGF receptor, with 10 which it shares structural similarities throughout (Yarden *et al.*, *Ann. Rev. Biochem.* 57:443-478 [1988]). When radioactive probes derived from the cDNA sequence encoding p185<sup>HER2</sup> were used to screen DNA samples from breast cancer patients, amplification of the HER2 protooncogene was observed in about 30% of the patient samples (Slamon *et al.*, *Science* 235:177-182 [1987]). Further studies have confirmed this original observation and extended it 15 to suggest an important correlation between HER2 protooncogene amplification and/or overexpression and worsened prognosis in ovarian cancer and non-small cell lung cancer (Slamon *et al.*, *Science* 244:707-712 [1989]); (Wright *et al.*, *Cancer Res* 49:2087-2090, 1989); (Paik *et al.*, *J. Clin. Oncology* 8:103-112 [1990]); (Berchuck *et al.*, *Cancer Res.* 50:4087-4091, 1990); (Kern *et al.*, *Cancer Res.* 50:5184-5191, 1990).

20 The association of HER2 amplification/overexpression with aggressive malignancy, as described above, implies that it may have an important role in progression of human cancer; however, many tumor-related cell surface antigens have been described in the past, few of which appear to have a direct role in the genesis or progression of disease (Schlom *et al.* *Cancer Res.* 50:820-827, 1990); (Szala *et al.*, *Proc. Natl. Acad. Sci.* 98:3542-3546).

25 Among the protooncogenes are those that encode cellular growth factors which act through endoplasmic kinase phosphorylation of cytoplasmic protein. The HER1 gene (or erb-B1) encodes the epidermal growth factor (EGF) receptor. The  $\beta$ -chain of platelet-derived growth factor is encoded by the c-sis gene. The granulocyte-macrophage colony stimulating factor is encoded by the c-fms gene. The *neu* protooncogene has been identified in 30 ethylnitrosourea-induced rat neuroblastomas. The HER2 gene encodes the 1,255 amino acid tyrosine kinase receptor-like glycoprotein p185<sup>HER2</sup> that has homology to the human epidermal growth factor receptor.

The known receptor tyrosine kinases all have the same general structural motif: an extracellular domain that binds ligand, and an intracellular tyrosine kinase domain that is 35 necessary for signal transduction and transformation. These two domains are connected by a single stretch of approximately 20 mostly hydrophobic amino acids, called the transmembrane spanning sequence. This transmembrane spanning sequence is thought to play a role in transferring the signal generated by ligand binding from the outside of the cell to the inside. Consistent with this general structure, the human p185<sup>HER2</sup> glycoprotein, which is



located on the cell surface, may be divided into three principal portions: an extracellular domain, or ECD (also known as XCD); a transmembrane spanning sequence; and a cytoplasmic, intracellular tyrosine kinase domain. While it is presumed that the extracellular domain is a ligand receptor, the p185<sup>HER2</sup> ligand has not yet been positively identified.

5       No specific ligand binding to p185<sup>HER2</sup> has been identified, although Lupu *et al.*, (*Science* 249:1552-1555, 1989) describe an inhibitory 30 kDa glycoprotein secreted from human breast cancer cells which is alleged to be a putative ligand for p185<sup>HER2</sup>. Lupu *et al.*, *Science*, 249:1552-1555 (1990); *Proceedings of the American Assoc. for Cancer Research*, Vol 32, Abs 297, March 1991) reported the purification of a 30 kD factor from MDA-MB-231 cells and a 75  
10   kD factor from SK-BR-3 cells that stimulates p185<sup>HER2</sup>. The 75 kD factor reportedly induced phosphorylation of p185<sup>HER2</sup> and modulated cell proliferation and colony formation of SK-BR-3 cells overexpressing the p185<sup>HER2</sup> receptor. The 30 kD factor competes with r<sup>h</sup>uMab 4D5 for binding to p185<sup>HER2</sup>, its growth effect on SK-BR-3 cells was dependent on 30 kD concentration (stimulatory at low concentrations and inhibitory at higher concentrations).  
15   Furthermore, it stimulated the growth of MDA-MB-468 cells (EGF-R positive, p185<sup>HER2</sup> negative), it stimulated phosphosylation of the EGF receptor and it could be obtained from SK-BR-3 cells. In the rat *neu* system, Yarden *et al.*, (*Biochemistry*, 30:3543-3550, 1991) describe a 35 kDa glycoprotein candidate ligand for the *neu* encoded receptor secreted by ras transformed fibroblasts. Dobashi *et al.*, *Proc. Natl. Acad. Sci. USA*, 88:8582-8586 (1991);  
20   *Biochem. Biophys. Res. Commun.*; 179:1536-1542 (1991) described a *neu* protein-specific activating factor (NAF) which is secreted by human T-cell line ATL-2 and which has a molecular weight in the range of 8-24 kD. A 25 kD ligand from activated macrophages was also described (Tarakhovsky, *et al.*, *J. Cancer Res.*, 2188-2196 (1991).

25       Methods for the *in vivo* assay of tumors using HER2 specific monoclonal antibodies and methods of treating tumor cells using HER2 specific monoclonal antibodies are described in WO89/06692.

There is a current and continuing need in the art to identify the actual ligand or ligands that activate p185<sup>HER2</sup>, and to identify their biological role(s), including their roles in cell-growth and differentiation, cell-transformation and the creation of malignant neoplasms.

30       Accordingly, it is an object of this invention to identify and purify one or more novel p185<sup>HER2</sup> ligand polypeptide(s) that bind and stimulate p185<sup>HER2</sup>.

It is another object to provide nucleic acid encoding novel p185<sup>HER2</sup> binding ligand polypeptides and to use this nucleic acid to produce a p185<sup>HER2</sup> binding ligand polypeptide in recombinant cell culture for therapeutic or diagnostic use, and for the production of therapeutic  
35   antagonists for use in certain metabolic disorders including, but not necessarily restricted to the killing, inhibition and/or diagnostic imaging of tumors and tumorigenic cells.

It is a further object to provide derivatives and modified forms of novel glycoprotein ligands, including amino acid sequence variants, fusion polypeptides combining a p185<sup>HER2</sup> binding ligand and a heterologous protein and covalent derivatives of a p185<sup>HER2</sup> binding ligand.

It is an additional object to prepare immunogens for raising antibodies against p185HER2 binding ligands, as well as to obtain antibodies capable of binding to such ligands, and antibodies which bind a p185HER2 binding ligand and prevent the ligand from activating p185HER2. It is a further object to prepare immunogens comprising a p185HER2 binding ligand fused with an immunogenic heterologous polypeptide.

These and other objects of the invention will be apparent to the ordinary artisan upon consideration of the specification as a whole.

### SUMMARY OF THE INVENTION

In accordance with the objects of this invention, we have identified and isolated novel ligand families which bind to p185HER2. These ligands are denominated the heregulin (HRG) polypeptides, and include HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2, HRG- $\beta$ 3 and other HRG polypeptides which cross-react with antibodies directed against these family members and/or which are substantially homologous as defined *infra*. A preferred HRG is the ligand disclosed in Fig. 4 and its fragments, further designated HRG- $\alpha$ . Other preferred HRGs are the ligands and their fragments disclosed in Figure 8, and designated HRG- $\beta$ 1, HRG- $\beta$ 2 disclosed in Figure 12, and HRG- $\beta$ 3 disclosed in Figure 13.

In another aspect, the invention provides a composition comprising HRG which is isolated from its source environment, in particular HRG that is free of contaminating human polypeptides. HRG is purified by absorption to heparin sepharose, cation (e.g. polyaspartic acid) exchange resins, and reversed phase HPLC.

HRG or HRG fragments (which also may be synthesized by *in vitro* methods) are fused (by recombinant expression or an *in vitro* peptidyl bond) to an immunogenic polypeptide and this fusion polypeptide, in turn, is used to raise antibodies against an HRG epitope. Anti-HRG antibodies are recovered from the serum of immunized animals. Alternatively, monoclonal antibodies are prepared from cells *in vitro* or from *in vivo* immunized animals in conventional fashion. Preferred antibodies identified by routine screening will bind to HRG, but will not substantially cross-react with any other known ligands such as EGF, and will prevent HRG from activating p185HER2. In addition, anti-HRG antibodies are selected that are capable of binding specifically to individual family members of the HRG family, e.g. HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2, HRG- $\beta$ 3, and thereby may act as specific antagonists thereof.

HRG also is derivatized *in vitro* to prepare immobilized HRG and labeled HRG, particularly for purposes of diagnosis of HRG or its antibodies, or for affinity purification of HRG antibodies. Immobilized anti-HRG antibodies are useful in the diagnosis (*in vitro* or *in vivo*) or purification of HRG. In one preferred embodiment, a mixture of HRG and other peptides is passed over a column to which the anti-HRG antibodies are bound.

Substitutional, deletional, or insertional variants of HRG are prepared by *in vitro* or recombinant methods and screened, for example, for immuno-crossreactivity with the native forms of HRG and for HRG antagonist or agonist activity.

In another preferred embodiment, HRG is used for stimulating the activity of p185<sup>HER2</sup> in normal cells. In another preferred embodiment, a variant of HRG is used as an antagonist to inhibit stimulation of p185<sup>HER2</sup>.

5 HRG, its derivatives, or its antibodies are formulated into physiologically acceptable vehicles, especially for therapeutic use. Such vehicles include sustained-release formulations of HRG or HRG variants. A composition is also provided comprising HRG and a pharmaceutically acceptable carrier, and an isolated polypeptide comprising HRG fused to a heterologous polypeptide.

10 In still other aspects, the invention provides an isolated nucleic acid encoding an HRG, which nucleic acid may be labeled or unlabeled with a detectable moiety, and a nucleic acid sequence that is complementary, or hybridizes under stringent conditions to, a nucleic acid sequence encoding an HRG.

15 The nucleic acid sequence is also useful in hybridization assays for HRG nucleic acid and in a method of determining the presence of an HRG, comprising hybridizing the DNA (or RNA) encoding (or complementary to) an HRG to a test sample nucleic acid and determining the presence of an HRG. The invention also provides a method of amplifying a nucleic acid test sample comprising priming a nucleic acid polymerase (chain) reaction with nucleic acid (DNA or RNA) encoding (or complementary to) a HRG.

20 In still further aspects, the nucleic acid is DNA and further comprises a replicable vector comprising the nucleic acid encoding an HRG operably linked to control sequences recognized by a host transformed by the vector; host cells transformed with the vector; and a method of using a nucleic acid encoding an HRG to effect the production of HRG, comprising expressing HRG nucleic acid in a culture of the transformed host cells and recovering an HRG from the host cell culture.

25 In further embodiments, the invention provides a method for producing HRG comprising inserting into the DNA of a cell containing the nucleic acid encoding an HRG a transcription modulatory element in sufficient proximity and orientation to an HRG nucleic acid to influence (suppress or stimulate) transcription thereof, with an optional further step comprising culturing the cell containing the transcription modulatory element and an HRG nucleic acid.

30 In still further embodiments, the invention provides a cell comprising the nucleic acid encoding an HRG and an exogenous transcription modulatory element in sufficient proximity and orientation to an HRG nucleic acid to influence transcription thereof; and a host cell containing the nucleic acid encoding an HRG operably linked to exogenous control sequences recognized by the host cell.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

35 **Figure 1** Purification of Heregulin on PolyAspartic Acid column.

PolyAspartic acid column chromatography of heregulin- $\alpha$  was conducted and the elution profile of proteins measured at A<sub>214</sub>. The 0.6 M NaCl pool from the heparin Sepharose purification step was diluted to 0.2 M NaCl with water and loaded onto the polyaspartic acid column equilibrated in 17 mM Na phosphate, pH 6.8 with 30% ethanol. A linear NaCl gradient

from 0.3 to 0.6 M was initiated at 0 time and was complete at 30 minutes. Fractions were tested in HRG tyrosine autophosphorylation assay. The fractions corresponding to peak C were pooled for further purification on C4 reversed phase HPLC.

**Figure 2** C4 Reversed Phase Purification of Heregulin-2.

5 Panel A: Pool C from the polyaspartic acid column was applied to a C4 HPLC column (SynChropak RP-4) equilibrated in 0.1% TFA and the proteins eluted with a linear acetonitrile gradient at 0.25%/minute. The absorbance trace for the run numbered C4-17 is shown. One milliliter fractions were collected for assay.

10 Panel B: Ten microliter aliquots of the fractions were tested in HRG tyrosine autophosphorylation assay. Levels of phosphotyrosine in the p185<sup>HER2</sup> protein were quantitated by a specific antiphosphotyrosine antibody and displayed in arbitrary units on the abscissa.

15 Panel C: Ten microliter fractions were taken and subjected to SDS gel electrophoresis on 4-20% acrylamide gradient gels according to the procedure of Laemmli (*Nature*, **227**:680-685, 1970). The molecular weights of the standard proteins are indicated to the left of the lane containing the standards. The major peak of tyrosine phosphorylation activity found in fraction 17 was associated with a prominent 45,000 Da band (HRG- $\alpha$ ).

**Figure 3.** SDS Polyacrylamide Gel Showing Purification of Heregulin- $\alpha$ .

20 Molecular weight markers are shown in Lane 1. Aliquots from the MDA-MB-231 conditioned media (Lane 2), the 0.6M NaCl pool from the heparin Sepharose column (Lane 3), Pool C from the polyaspartic acid column (Lane 4) and Fraction 17 from the HPLC column (C4-17) (Lane 5) were electrophoresed on a 4-20% gradient gel and silver stained. Lanes 6 and 7 contained buffer only and shows the presence of gel artifacts in the 50-65 KDa molecular weight region.

25 **Figures 4a-4d** depict the deduced amino acid sequence of the cDNA contained in  $\lambda$ gt10her16 (SEQ ID NO:12 and SEQ ID NO:13). The nucleotides are numbered at the top left of each line and the amino acids written in three letter code are numbered at the bottom left of each line. The nucleotide sequence corresponding to the probe is nucleotides 681-720. The probable transmembrane domain is amino acids 287-309. The six cysteines of the EGF motif are 226, 234, 240, 254, 256 and 265. The five potential three-amino acid N-linked glycosylation sites are 164-166, 170-172, 208-210, 437-439 and 609-611. The serine-threonine potential O-glycosylation sites are 209-221. Serine-glycine dipeptide potential glycosaminoglycan addition sites are amino acids 42-43, 64-65 and 151-152. The initiating methionine(MET) is at position 30 #45 of figure 4 although the processed N-terminal residue is S46.

35 **Figure 5** Northern blot analysis of MDA-MB-231 and SKBR3 RNAs Labeled from left to right are the following: 1) MDA-MB-231 polyA minus-RNA, (RNA remaining after polyA-containing RNA is removed); 2) MDA-MB-231 polyA plus-mRNA (RNA which contains polyA); 3) SKBR3 polyA minus-RNA; and, 4) SKBR3 polyA plus-mRNA. The probe used for this

analysis was a radioactively ( $^{32}\text{P}$ ) labelled internal xho1 DNA restriction endonuclease fragment from the cDNA portion of  $\lambda\text{gt10her16}$ .

**Figure 6** Sequence Comparisons in the EGF Family of Proteins.

Sequences of several EGF-like proteins (SEQ ID NOS: 14, 15, 16, 17, 18, and 19) around the cysteine domain are aligned with the sequence of HRG- $\alpha$ . The location in figure 6 of the cysteines and the invariant glycine and arginine residues at positions 238 and 264 clearly show that HRG- $\alpha$  is a member of the EGF family. The region in figure 6 of highest amino acid identity of the family members relative to HRG- $\alpha$  (30-40%) is found between Cys 234 and Cys 265. The strongest identity (40%) is with the heparin-binding EGF (HB-EGF) species. HRG- $\alpha$  has a unique 3 amino acid insert between Cys 240 and Cys 254. Potential transmembrane domains are boxed (287-309). Bars indicate the carboxy-terminal sites for EGF and TGF- $\alpha$  where proteolytic cleavage detaches the mature growth factors from their transmembrane associated proforms. HB-EGF is heparin binding-epidermal growth factor; EGF is epidermal growth factor; TGF- $\alpha$  is transforming growth factor alpha; and schwannoma is the schwannoma-derived growth factor. The residue numbers in Fig. 6 reflect the Fig. 4 convention.

**Figure 7** Stimulation of Cell Growth by HRG- $\alpha$ .

Three different cell lines were tested for growth responses to 1 nM HRG- $\alpha$ . Cell protein was quantitated by crystal violet staining and the responses normalized to control, untreated cells.

**Figures 8a-8d** (SEQ ID NO:7) depict the entire potential coding DNA nucleotide sequence of the heregulin- $\beta$ 1 and the deduced amino acid sequence of the cDNA contained in  $\lambda\text{her 11.1db1}$  (SEQ ID NO:9). The nucleotides are numbered at the top left of each line and the amino acids written in three letter code are numbered at the bottom left of each line. The probable transmembrane amino acid domain is amino acids 278-300. The six cysteines of the EGF motif are 212, 220, 226, 240, 242 and 251. The five potential three-amino acid N-linked glycosylation sites are 150-152, 156-158, 196-198, 428-430 and 600-612. The serine-threonine potential O-glycosylation sites are 195-207. Serine-glycine dipeptide potential glycosaminoglycan addition sites are amino acids 28-29, 50-51 and 137-138. The initiating methionine (MET) is at position #31. HRG- $\beta$ 1 is processed to the N-terminal residue S32.

**Figure 9** depicts a comparison of the amino acid sequences of heregulin- $\alpha$  and - $\beta$ 1. A dash (-) indicates no amino acid at that position. (SEQ ID NO:8 and SEQ ID NO:9). This Fig. uses the numbering convention of Figs. 4 and 6.

**Figure 10** shows the stimulation of HER2 autophosphorylation using recombinant HRG- $\alpha$  as measured by HER2 tyrosine phosphorylation.

**Figure 11** depicts the nucleotide and inputted amino acid sequence of  $\lambda\text{15'her13}$  (SEQ ID NO:22); the amino acid residue numbering convention is unique to this figure.

Figure 12a-12e depict the nucleotide sequence of  $\lambda$ her76, encoding heregulin- $\beta$ 2 (SEQ ID NO:23). This figure commences amino acid residue numbering with the expressed N-terminal MET; the N-terminus is S2.

Figures 13a-13c depict the nucleotide sequence of  $\lambda$ her78, encoding heregulin- $\beta$ 3 (SEQ ID NO:24). This figure uses the amino acid numbering convention of Fig. 12; S2 is the processed N-terminus.

Figures 14a-14d depict the nucleotide sequence of  $\lambda$ her84, encoding a heregulin- $\beta$ 2-like polypeptide (SEQ ID NO:25). This figure uses the amino acid numbering convention of Fig. 12; S2 is the processed N-terminus.

Figure 15a-15c depict the amino acid homologies between the known heregulins ( $\alpha$ ,  $\beta$ 1,  $\beta$ 2,  $\beta$ 2-like and  $\beta$ 3 in descending order) and illustrates the amino acid insertions, deletions or substitutions that distinguish the different forms (SEQ ID NOS:26-30). This figure uses the amino acid numbering convention of Figs. 12-14.

## 15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

### 1 Definitions

In general, the following words or phrases have the indicated definition when used in the description, examples, and claims.

Heregulin ("HRG") is defined herein to be any isolated polypeptide sequence which possesses a biological activity of a polypeptide disclosed in Figs. 4, 8, 12, 13, or 15, and fragments, alleles or animal analogues thereof or their animal analogues. HRG excludes any polypeptide heretofore identified, including any known polypeptide which is otherwise anticipatory under 35 U.S.C. 102, as well as polypeptides obvious over such known polypeptides under 35 U.S.C. 103, including in particular EFG, TFG- $\alpha$ , amphiregulin (Plowman *et al. Mol. Cell. Biol.* 10:1969 (1990), HB-EGF (Higashimaya *et al., Science* 251:936 [1991]), schwannoma factor or polypeptides obvious thereover.

"Biological activity" for the purposes herein means an *in vivo* effector or antigenic function that is directly or indirectly performed by an HRG polypeptide (whether in its native or denatured conformation), or by any subsequence thereof. Effector functions include receptor binding or activation, induction of differentiation, mitogenic or growth promoting activity, immune modulation, DNA regulatory functions and the like, whether presently known or inherent. Antigenic functions include possession of an epitope or antigenic site that is capable of cross-reacting with antibodies raised against a naturally occurring or denatured HRG polypeptide or fragment thereof.

Biologically active HRG includes polypeptides having both an effector and antigenic function, or only one of such functions. HRG includes antagonist polypeptides to HRG, provided that such antagonists include an epitope of a native HRG. A principal known effector function of HRG is its ability to bind to p185<sup>HER2</sup> and activate the receptor tyrosine kinase.

HRG includes the translated amino acid sequence of full length human HRGs (proHRG) set forth herein in the Figures; deglycosylated or unglycosylated derivatives; amino acid sequence variants; and covalent derivatives of HRG, provided that they possess biological activity. While the native proform of HRG is probably a membrane-bound polypeptide, soluble forms, such as those forms lacking a functional transmembrane domain (proHRG or its fragments), are also included within this definition.

Fragments of intact HRG are included within the definition of HRG. Two principal domains are included within the fragments. These are the growth factor domain ("GFD"), homologous to the EGF family and located at about residues S216-A227 to N268-R286 (Fig. 9, HRG- $\alpha$ ; the GFD domains for other HRGs (Fig. 15) are the homologous sequences.). Preferably, the GFDs for HRG- $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\beta_2$ -like and  $\beta_3$  are, respectively, G175-K241, G175-K246, G175-K238, G175-K238 and G175-E241 (Fig. 15).

Another fragment of interest is the N-terminal domain ("NTD"). The NTD extends from the N-terminus of processed HRG (S2) to the residue adjacent to an N-terminal residue of the GFD, i.e., about T172-C182 (Fig. 15) and preferably T174. An additional group of fragments are NTD-GFD domains, equivalent to the extracellular domains of HRG- $\alpha$  and  $\beta_1$ - $\beta_2$ . Another fragment is the C-terminal peptide ("CTP") located about 20 residues N-terminal to the first residue of the transmembrane domain, either alone or in combination with the C-terminal remainder of the HRG.

In preferred embodiments, antigenically active HRG is a polypeptide that binds with an affinity of at least about  $10^7$  l/mole to an antibody raised against a naturally occurring HRG sequence. Ordinarily the polypeptide binds with an affinity of at least about  $10^8$  l/mole. Most preferably, the antigenically active HRG is a polypeptide that binds to an antibody raised against one of HRGs in its native conformation. HRG in its native conformation generally is HRG as found in nature which has not been denatured by chaotropic agents, heat or other treatment that substantially modifies the three dimensional structure of HRG as determined, for example, by migration on nonreducing, nondenaturing sizing gels. Antibody used in this determination is rabbit polyclonal antibody raised by formulating native HRG from a non-rabbit species in Freund's complete adjuvant, subcutaneously injecting the formulation into rabbits, and boosting the immune response by intraperitoneal injection of the formulation until the titer of anti-HRG antibody plateaus.

Ordinarily, biologically active HRG will have an amino acid sequence having at least 75% amino acid sequence identity with an HRG sequence, more preferably at least 80%, even more preferably at least 90%, and most preferably at least 95%. Identity or homology with respect to an HRG sequence is defined herein as the percentage of amino acid residues in the candidate sequence that are identical with HRG residues in Figs. 15, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent homology, and not considering any conservative substitutions to be identical residues. None of N-terminal,

C-terminal or internal extensions, deletions, or insertions into HRG sequence shall be construed as affecting homology.

Thus, the biologically active HRG polypeptides that are the subject of this invention include each expressed or processed HRG sequence; fragments thereof having a consecutive  
5 sequence of at least 5, 10, 15, 20, 25, 30 or 40 amino acid residues; amino acid sequence variants of HRG wherein an amino acid residue has been inserted N- or C-terminal to, or within, HRG sequence or its fragment as defined above; amino acid sequence variants of HRG sequence or its fragment as defined above wherein a residue has been substituted by another residue. HRG polypeptides include those containing predetermined mutations by, e.g., site-  
10 directed or PCR mutagenesis. HRG includes HRG from such as species as rabbit, rat, porcine, non-human primate, equine, murine, and ovine HRG and alleles or other naturally occurring variants of the foregoing; derivatives of HRG or its fragments as defined above wherein HRG or its fragments have been covalently modified by substitution, chemical, enzymatic, or other appropriate means with a moiety other than a naturally occurring amino  
15 acid (for example a detectable moiety such as an enzyme or radioisotope); glycosylation variants of HRG (insertion of a glycosylation site or deletion of any glycosylation site by deletion, insertion or substitution of an appropriate residue); and soluble forms of HRG, such as HRG-GFD or those that lack a functional transmembrane domain.

Of particular interest are fusion proteins that contain HRG-NTD but are free of the  
20 GFD ordinarily associated with the HRG-NTD in question. The first 23 amino acids of the NTD are dominated by charged residues and contain a sequence (GKKKER; residues 13-18, Fig. 15) that closely resembles the consensus sequence motif for nuclear targeting (Roberts, Biochim. Biophys. Acta. 1008:263 [1989]). Accordingly, the HRG includes fusions in which the NTD, or at least a polypeptide comprising its first about 23 residues, is fused at a terminus  
25 to a non-HRG polypeptide or to a GFD of another HRG family member. The non-HRG polypeptide in this embodiment is a regulatory protein, a growth factor such as EGF or TGF- $\alpha$ , or a polypeptide ligand that binds to a cell receptor, particularly a cell surface receptor found on the surface of a cell whose regulation is desired, e.g. a cancer cell.

In another embodiment, one or more of residues 13-18 independently are varied to  
30 produce a sequence incapable of nuclear targeting. For example G13 is mutated to any other naturally occurring residue including P, L, I, V, A, M, F, K, D or S; any one or more of K14-K16 are mutated to any other naturally occurring residue including R, H, D, E, N or Q; E17 to any other naturally occurring residue including D, R, K, H, N or Q; and R18 to any other naturally occurring residue including K, H, D, E, N or Q. All or any one of residues 13-18 are deleted as  
35 well, or extraneous residues are inserted adjacent to these residues; for example residues inserted adjacent to residue 13-18 which are the same as the above- suggested substitutions for the residues themselves.

In another embodiment, enzymes or a nuclear regulatory protein such as a transcriptional regulatory factor is fused to HRG-NTD, HRG-NTD-GFD, or HRG-GFD. The



enzyme or factor is fused to the N- or C- terminus, or inserted between the NTD and GFD domains, or is substituted for the region of NTD between the first about 23 residues and the GFD.

"Isolated" HRG means HRG which has been identified and is free of components of its natural environment. Contaminant components of its natural environment include materials which would interfere with diagnostic or therapeutic uses for HRG, and may include proteins, hormones, and other substances. In preferred embodiments, HRG will be purified (1) to greater than 95% by weight of protein as determined by the Lowry method or other validated protein determination method, and most preferably more than 99% by weight, (2) to a degree sufficient to obtain at least 15 residues of N-terminal or internal amino acid sequence by use of the best commercially available amino acid sequenator marketed on the filing date hereof, or (3) to homogeneity by SDS-PAGE using Coomassie blue or, preferably, silver stain. Isolated HRG includes HRG in situ within heterologous recombinant cells since at least one component of HRG natural environment will not be present. Isolated HRG includes HRG from one species in a recombinant cell culture of another species since HRG in such circumstances will be devoid of source polypeptides. Ordinarily, however, isolated HRG will be prepared by at least one purification step.

In accordance with this invention, HRG nucleic acid is RNA or DNA containing greater than ten bases that encodes a biologically or antigenically active HRG, is complementary to nucleic acid sequence encoding such HRG; or hybridizes to nucleic acid sequence encoding such HRG and remains stably bound to it under stringent conditions.

Preferably, HRG nucleic acid encodes a polypeptide sharing at least 75% sequence identity, more preferably at least 80%, still more preferably at least 85%, even more preferably at 90%, and most preferably 95%, with an HRG sequence. Preferably, the HRG nucleic acid that hybridizes contains at least 20, more preferably at least about 40, and most preferably at least about 90 bases. Such hybridizing or complementary nucleic acid, however, is further defined as being novel under 35 U.S.C. 102 and unobvious under 35 U.S.C. 103 over any prior art nucleic acid and excludes nucleic acid encoding EGF, TGF- $\alpha$ , amphiregulin, HB-EGF, schwannoma factor or fragments or variants thereof which would have been obvious as of the filing date hereof.

Isolated HRG nucleic acid includes a nucleic acid that is free from at least one contaminant nucleic acid with which it is ordinarily associated in the natural source of HRG nucleic acid. Isolated HRG nucleic acid thus is present in other than in the form or setting in which it is found in nature. However, isolated HRG encoding nucleic acid includes HRG nucleic acid in ordinarily HRG-expressing cells where the nucleic acid is in a chromosomal location different from that of natural cells or is otherwise flanked by a different DNA sequence than that found in nature. Nucleic acid encoding HRG may be used in specific hybridization assays, particularly those portions of HRG encoding sequence that do not hybridize with other known DNA sequences, for example those encoding the EGF-like molecules of figure 6.

"Stringent conditions" are those that (1) employ low ionic strength and high temperature for washing, for example, 0.015 M NaCl/0.0015 M sodium citrate/0.1% NaDodSO<sub>4</sub> at 50° C; (2) employ during hybridization a denaturing agent such as formamide, for example, 50% (vol/vol) formamide with 0.1% bovine serum albumin, 0.1% Ficoll, 0.1% polyvinylpyrrolidone, 50 mM sodium phosphate buffer at pH 6.5 with 750 mM NaCl, 75 mM sodium citrate at 42° C; or (3) employ 50% formamide, 5 x SSC (0.75 M NaCl, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5 x Denhardt's solution, sonicated salmon sperm DNA (50 g/ml), 0.1% SDS, and 10% dextran sulfate at 42°C, with washes at 42°C in 0.2 x SSC and 0.1% SDS.

Particular HRG- $\alpha$  nucleic acids are nucleic acids or oligonucleotides consisting of or comprising a nucleotide sequence selected from Figs. 4a-4d and containing greater than 17 bases (when excluding nucleic acid sequences of human small polydisperse circular DNA (HUMPC125), chicken c-mos proto-oncogene homolog (CHKMOS), basement membrane heparin sulfate proteoglycan (HUMBMHSP) and human lipocortin 2 pseudogene (complete cds-like region, HUMLIP2B), ordinarily greater than 20 bases, preferably greater than 25 bases, together with the complementary sequences thereof.

Particular HRG- $\beta_1$ , - $\beta_2$  or - $\beta_3$  nucleic acids are nucleic acids or oligonucleotides consisting of or comprising a nucleotide sequence selected from Figs. 8a-8d, 12a-12e or 13a-13c and containing greater than 20 bases, but does not include the polyA sequence found at the 3' end of each gene as noted in the Figures, together with the complements to such sequences. Preferably the sequence contains greater than 25 bases. HRG- $\beta$  sequences also may exclude the human small polydisperse circular DNA sequence (HUMP-C125).

In other embodiments, the HRG nucleotide sequence contains a 15 or more base HRG sequence and is selected from within the sequence encoding the HRG domain extending from the N-terminus of the GFD to the N-terminus of the transmembrane sequence (or the complement of that nucleic acid sequence). For example, with respect to HRG- $\alpha$ , the nucleotide sequence is selected from within the sequence 678-869 (Fig. 4b) and contains a sequence of 15 or more bases from this section of the HRG nucleic acid.

In other embodiments, the HRG nucleic acid sequence is greater than 14 bases and is selected from a nucleotide sequence unique to each subtype, for instance a nucleic acid sequence encoding an amino acid sequence that is unique to each of the HRG subtypes (or the complement of that nucleic acid sequence). These sequences are useful in diagnostic assays for expression of the various subtypes, as well as specific amplification of the subtype DNA. For example, the HRG- $\alpha$  sequence of interest would be selected from the sequence encoding the unique N-terminus or GFD-transmembrane joining sequence, e.g. about bp771-860. Similarly, a unique HRG- $\beta_1$  sequence is that which encodes the last 15 C-terminal amino acid residues; this sequence is not found in HRG- $\alpha$ .

In general, the length of the HRG- $\alpha$  or  $\beta$  sequence beyond greater than the above-indicated number of bases is immaterial since all of such nucleic acids are useful as probes or amplification primers. The selected HRG sequence may contain additional HRG sequence, either the normal flanking sequence or other regions of the HRG nucleic acid, as well as other  
5 nucleic acid sequences. For purposes of hybridization, only the HRG sequence is material.

The term "control sequences" refers to DNA sequences necessary for the expression of an operably linked coding sequence in a particular host organism. The control sequences that are suitable for prokaryotes, for example, include a promoter, optionally an operator sequence, a ribosome binding site, and possibly, other as yet poorly understood sequences.  
10 Eukaryotic cells are known to utilize promoters, polyadenylation signals, and enhancers.

Nucleic acid is "operably linked" when it is placed into a functional relationship with another nucleic acid sequence. For example, DNA for a presequence or secretory leader is operably linked to DNA for a polypeptide if it is expressed as a preprotein that participates in the secretion of the polypeptide; a promoter or enhancer is operably linked to a coding  
15 sequence if it affects the transcription of the sequence; or a ribosome binding site is operably linked to a coding sequence if it is positioned so as to facilitate translation. Generally, "operably linked" means that the DNA sequences being linked are contiguous and, in the case of a secretory leader, contiguous and in reading phase. However enhancers do not have to be contiguous. Linking is accomplished by ligation at convenient restriction sites. If such sites do  
20 not exist, then synthetic oligonucleotide adaptors or linkers are used in accord with conventional practice.

An "exogenous" element is defined herein to mean nucleic acid sequence that is foreign to the cell, or homologous to the cell but in a position within the host cell nucleic acid in which the element is ordinarily not found.

25 As used herein, the expressions "cell", "cell line", and "cell culture" are used interchangeably, and all such designations include progeny. Thus, the words "transformants" and "transformed cells" include the primary subject cell and cultures derived therefrom without regard for the number of transfers. It is also understood that all progeny may not be precisely identical in DNA content, due to deliberate or inadvertent mutations. Mutant progeny that  
30 have the same function or biological activity as screened for in the originally transformed cell are included. It will be clear from the context where distinct designations are intended.

"Plasmids" are designated by a lower case "p" preceded and/or followed by capital letters and/or numbers. The starting plasmids herein are commercially available, are publicly available on an unrestricted basis, or can be constructed from such available plasmids in  
35 accord with published procedures. In addition, other equivalent plasmids are known in the art and will be apparent to the ordinary artisan.

"Restriction Enzyme Digestion" of DNA refers to catalytic cleavage of the DNA with an enzyme that acts only at certain locations in the DNA. Such enzymes are called restriction endonucleases, and the sites for which each is specific is called a restriction site.

The various restriction enzymes used herein are commercially available and their reaction conditions, cofactors, and other requirements as established by the enzyme suppliers are used. Restriction enzymes commonly are designated by abbreviations composed of a capital letter followed by other letters representing the microorganism from which each restriction enzyme originally was obtained, and then a number designating the particular enzyme. In general, about 1  $\mu$ g of plasmid or DNA fragment is used with about 1-2 units of enzyme in about 20  $\mu$ l of buffer solution. Appropriate buffers and substrate amounts for particular restriction enzymes are specified by the manufacturer. Incubation of about 1 hour at 37°C is ordinarily used, but may vary in accordance with the supplier's instructions. After incubation, protein or polypeptide is removed by extraction with phenol and chloroform, and the digested nucleic acid is recovered from the aqueous fraction by precipitation with ethanol. Digestion with a restriction enzyme may be followed with bacterial alkaline phosphatase hydrolysis of the terminal 5' phosphates to prevent the two restriction cleaved ends of a DNA fragment from "circularizing" or forming a closed loop that would impede insertion of another DNA fragment at the restriction site. Unless otherwise stated, digestion of plasmids is not followed by 5' terminal dephosphorylation. Procedures and reagents for dephosphorylation are conventional as described in sections 1.56-1.61 of Sambrook *et al.*, (*Molecular Cloning: A Laboratory Manual* New York: Cold Spring Harbor Laboratory Press, 1989).

"Ligation" refers to the process of forming phosphodiester bonds between two nucleic acid fragments. To ligate the DNA fragments together, the ends of the DNA fragments must be compatible with each other. In some cases, the ends will be directly compatible after endonuclease digestion. However, it may be necessary to first convert the staggered ends commonly produced after endonuclease digestion to blunt ends to make them compatible for ligation. To blunt the ends, the DNA is treated in a suitable buffer for at least 15 minutes at 15°C with about 10 units of the Klenow fragment of DNA polymerase I or T4 DNA polymerase in the presence of the four deoxyribonucleotide triphosphates. The DNA is then purified by phenol-chloroform extraction and ethanol precipitation. The DNA fragments that are to be ligated together are put in solution in about equimolar amounts. The solution will also contain ATP, ligase buffer, and a ligase such as T4 DNA ligase at about 10 units per 0.5  $\mu$ g of DNA. If the DNA is to be ligated into a vector, the vector is first linearized by digestion with the appropriate restriction endonuclease(s). The linearized fragment is then treated with bacterial alkaline phosphatase, or calf intestinal phosphatase to prevent self-ligation during the ligation step.

The technique of "polymerase chain reaction," or "PCR," as used herein generally refers to a procedure wherein minute amounts of a specific piece of nucleic acid, RNA and/or DNA, are amplified as described in U.S. Pat. No. 4,683,195, issued 28 July 1987. Generally, sequence information from the ends of the region of interest or beyond needs to be available, such that oligonucleotide primers can be designed; these primers will be identical or similar in sequence to opposite strands of the template to be amplified. The 5' terminal nucleotides of

the two primers may coincide with the ends of the amplified material. PCR can be used to amplify specific RNA sequences, specific DNA sequences from total genomic DNA, and cDNA transcribed from total cellular RNA, bacteriophage or plasmid sequences, etc. See generally Mullis *et al.*, *Cold Spring Harbor Symp. Quant. Biol.* 51: 263 (1987); Erlich, ed., *PCR Technology*, (Stockton Press, NY, 1989). As used herein, PCR is considered to be one, but not the only, example of a nucleic acid polymerase reaction method for amplifying a nucleic acid test sample, comprising the use of a known nucleic acid (DNA or RNA) as a primer, and utilizes a nucleic acid polymerase to amplify or generate a specific piece of nucleic acid or to amplify or generate a specific piece of nucleic acid which is complementary to a particular nucleic acid.

The "HRG tyrosine autophosphorylation assay" to detect the presence of HRG ligands was used to monitor the purification of a ligand for the p185<sup>HER2</sup> receptor. This assay is based on the assumption that a specific ligand for the p185<sup>HER2</sup> receptor will stimulate autophosphorylation of the receptor, in analogy with EGF and its stimulation of EGF receptor autophosphorylation. MDA-MB-453 cells or MCF7 cells which contain high levels of p185<sup>HER2</sup> receptors but negligible levels of human EGF receptors, were obtained from the American Type Culture Collection, Rockville, Md. (ATCC No HTB-131) and maintained in tissue culture with 10% fetal calf serum in DMEM/Hams F12 (1:1) media. For assay, the cells were trypsinized and plated at about 150,000 cells/well in 24 well dishes (Costar). After incubation with serum containing media overnight, the cells were placed in serum free media for 2-18 hours before assay. Test samples of 100 uL aliquots were added to each well. The cells were incubated for 5-30 minutes (typically 30 min) at 37°C and the media removed. The cells in each well were treated with 100 uL SDS gel denaturing buffer (Seprosol, Enpotech, Inc.) and the plates heated at 100°C for 5 minutes to dissolve the cells and denature the proteins. Aliquots from each well were electrophoresed on 5-20% gradient SDS gels (Novex, Encinitas, CA) according to the manufacturer's directions. After the dye front reached the bottom of the gel, the electrophoresis was terminated and a sheet of PVDF membrane (ProBlott, ABI) was placed on the gel and the proteins transferred from the gel to the membrane in a blotting chamber (BioRad) at 200 mAmps for 30-60 min. After blotting, the membranes were incubated with Tris buffered saline containing 0.1% Tween 20 detergent buffer with 5% BSA for 2-18 hrs to block nonspecific binding, and then treated with a mouse anti-phosphotyrosine antibody (Upstate Biological Inc., N.Y.). Subsequently, the membrane blots were treated with goat anti-mouse antibody conjugated to alkaline phosphatase. The gels were developed using the ProtoBlot System from Promega. After drying the membranes, the density of the bands corresponding to p185<sup>HER2</sup> in each sample lane was quantitated with a Hewlett Packard ScanJet Plus Scanner attached to a Macintosh computer. The number of receptors per cell in the MDA-MB-453 or MCF-7 cells is such that under these experimental conditions the p185<sup>HER2</sup> receptor protein is the major protein which is labeled.

"Protein microsequencing" was accomplished based upon the following procedures. Proteins from the final HPLC step were either sequenced directly by automated Edman degradation with a model 470A Applied Biosystems gas phase sequencer equipped with a 120A PTH amino acid analyzer or sequenced after digestion with various chemicals or enzymes. PTH amino acids were integrated using the ChromPerfect data system (Justice Innovations, Palo Alto, CA). Sequence interpretation was performed on a VAX 11/785 Digital Equipment Corporation computer as described (Henzel *et al.*, *J. Chromatography* 404:41-52 (1987)). In some cases, aliquots of the HPLC fractions were electrophoresed on 5-20% SDS polyacrylamide gels, electrotransferred to a PVDF membrane (ProBlott, ABI, Foster City, CA) and stained with Coomassie Brilliant Blue (Matsudaira, P., *J. Biol. Chem.* 262:10035-10038, 1987). The specific protein was excised from the blot for N terminal sequencing. To determine internal protein sequences, HPLC fractions were dried under vacuum (SpeedVac), resuspended in appropriate buffers, and digested with cyanogen bromide, the lysine-specific enzyme Lys-C (Wako Chemicals, Richmond, VA) or Asp-N (Boehringer Mannheim, Indianapolis, Ind.). After digestion, the resultant peptides were sequenced as a mixture or were resolved by HPLC on a C4 column developed with a propanol gradient in 0.1% TFA before sequencing as described above.

## II. USE AND PREPARATION OF HRG POLYPEPTIDES

### 1. PREPARATION OF HRG POLYPEPTIDES INCLUDING VARIANTS

The system to be employed in preparing HRG polypeptides will depend upon the particular HRG sequence selected. If the sequence is sufficiently small HRG is prepared by in vitro polypeptide synthetic methods. Most commonly, however, HRG is prepared in recombinant cell culture using the host-vector systems described below.

In general, mammalian host cells will be employed, and such hosts may or may not contain post-translational systems for processing HRG prosequences in the normal fashion. If the host cells contain such systems then it will be possible to recover natural subdomain fragments such as HRG-GFD OR HRG-NTD-GFD from the cultures. If not, then the proper processing can be accomplished by transforming the hosts with the required enzyme(s) or by cleaving the precursor in vitro. However, it is not necessary to transform cells with DNA encoding the complete prosequence for a selected HRG when it is desired to only produce fragments of HRG sequences such as an HRG-GFD. For example, to prepare HRG-GFD a start codon is ligated to the 5' end of DNA encoding an HRG-GFD, this DNA is used to transform host cells and the product expressed directly as the Met N-terminal form (if desired, the extraneous Met may be removed in vitro or by endogenous N-terminal demethionylases). Alternatively, HRG-GFD is expressed as a fusion with a signal sequence recognized by the host cell, which will process and secrete the mature HRG-GFD as is further described below. Amino acid sequence variants of native HRG-GFD sequences are produced in the same way.

HRG-NTD is produced in the same fashion as the full length molecule but from expression of DNA encoding only HRG-NTD, with the stop codon after one of S172-C182 (Fig. 15).

In addition, HRG variants are expressed from DNA encoding protein in which both the  
5 GFD and NTD domains are in their proper orientation but which contain an amino acid insertion, deletion or substitution at the NTD-GFD joining site (for example located within the sequence S172-C182. In another embodiment a stop codon is positioned at the 3' end of the NTD-GFD-encoding sequence (after any residue T/Q222-T245 of Fig. 15). The result is a soluble form of HRG- $\alpha$  or - $\beta_1$  or - $\beta_2$  which lacks its transmembrane sequence (this sequence  
10 also may be an internal signal sequence but will be referred to as a transmembrane sequence). In further variations of this embodiment, an internal signal sequence of another polypeptide is substituted in place of the native HRG transmembrane domain, or a cytoplasmic domain of another cell membrane polypeptide, e.g. receptor kinase, is substituted for the HRG- $\alpha$  or HRG  $\beta_1$ - $\beta_2$  cytoplasmic peptide.

15 In a still further embodiment, the NTD, GFD and transmembrane domains of HRG and other EGF family members are substituted for one another, e.g. the NTD equivalent region of EGF is substituted for the NTD of HRG, or the GFD of HRG is substituted for EGF in the processed, soluble proform of EGF. Alternatively, an HRG or EGF family member transmembrane domain is fused onto the C-terminal E236 of HRG- $\beta_3$ .

20 In a further variant, the HRG sequence spanning K241 to the C-terminus is fused at its N-terminus to the C-terminus of a non-HRG polypeptide.

Another embodiment comprises the functional or structural deletion of the proteolytic processing site in CTP, the GFD-transmembrane spanning domain. For example, the putative C-terminal lysine (K241) of processed HRG- $\alpha$  or  $\beta_1$ - $\beta_2$  is deleted, substituted with another  
25 residue, a residue other than K or R inserted between K241 and R242, or other disabling mutation is made in the prosequence.

In another embodiment, the domain of any EGF family member extending from (a) its cysteine corresponding to (b) C221 to the C-terminal residue of the family member is substituted for the analogous domain of HRG- $\alpha$  or - $\beta_1$  or - $\beta_2$  (or fused to the C-terminus of  
30 HRG- $\beta_3$ ). Such variants will be processed free of host cells in the same fashion as the family member rather than as the parental HRG. In more refined embodiments other specific cleavage sites (e.g. protease sites) are substituted into the CTP or GFD-transmembrane spanning domain (about residues T/Q222-T245, Fig. 15). For example, amphiregulin sequence E84-K99 or TGF $\alpha$  sequence E44-K58 is substituted for HRG- $\alpha$  residues E223-K241.

35 In a further embodiment, a variant (termed HRG-NTDxGFD) is prepared wherein (1) the lysine residue found in the NTD-GFD joining sequence VKC (residues 180-182, Figure 15) is deleted or (preferably) substituted by another residue other than R such as H, A, T or S and (2) a stop codon is introduced in the sequence RCT or RCQ (residues 220-222, Figure 15) in place of C, or T (for HRG- $\alpha$ ) or Q (for HRG-beta).

A preferred HRG- $\alpha$  ligand with binding affinity to p185<sup>HER2</sup> comprises amino acids 226-265 of figure 4. This HRG- $\alpha$  ligand further may comprise up to an additional 1-20 amino acids preceding amino acid 226 from figure 4 and 1-20 amino acids following amino acid 265 from figure 4. A preferred HRG- $\beta$  ligand with binding affinity to p185<sup>HER2</sup> comprises amino acids 226-265 of figure 8. This HRG- $\beta$  ligand may comprise up to an additional 1-20 amino acids preceding amino acid 226 from figure 8 and 1-20 amino acids following amino acid 265 from figure 8.

GFD sequences include those in which one or more residues corresponding to another member of the EGF family are deleted or substituted or have a residue inserted adjacent thereto. For example, F216 of HRG is substituted by Y, L202 with E, F189 with Y, or S203-P205 is deleted.

HRG also includes NTD-GFD having its C-terminus at one of the first about 1 to 3 extracellular domain residues (QKR, residues 240-243, HRE- $\alpha$ , Figure 15) or first about 1-2 transmembrane region residues. In addition, in some HRG-GFD variants the codons are modified at the GFD-transmembrane propeptolysis site by substitution, insertion or deletion. The GFD proteolysis site is the domain that contains the GFD C-terminal residue and about 5 residues N- and 5 residues C-terminal from this residue. At this time neither the natural C-terminal residue for HRG- $\alpha$  or HRG- $\beta$  has been identified, although it is known that Met-227 terminal and Val-229 terminal HRG- $\alpha$ -GFD are biologically active. The native C-terminus for HRG- $\alpha$ -GFD is probably Met-227, Lys-228, Val-229, Gln-230, Asn-231 or Gln-232, and for HRG  $\beta_1$ - $\beta_2$ -GFD is probably Met-226, Ala-227, Ser-228, Phe-229, Trp-230, Lys 231 or (for HRG- $\beta_1$ ) K240 or (for HRG- $\beta_2$ ) K246. The native C-terminus is determined readily by C-terminal sequencing, although it is not critical that HRG-GFD have the native terminus so long as the GFD sequence possesses the desired activity. In some embodiments of HRG-GFD variants, the amino acid change(s) in the CTP are screened for their ability to resist proteolysis *in vitro* and inhibit the protease responsible for generation of HRG-GFD.

If it is desired to prepare the full length HRG polypeptides and the 5' or 3' ends of the given HRG are not described herein, it may be necessary to prepare nucleic acids in which the missing domains are supplied by homologous regions from more complete HRG nucleic acids. Alternatively, the missing domains can be obtained by probing libraries using the DNAs disclosed in the Figures or fragments thereof.

#### A. Isolation of DNA Encoding Heregulin

The DNA encoding HRG may be obtained from any cDNA library prepared from tissue believed to possess HRG mRNA and to express it at a detectable level. HRG DNA also is obtained from a genomic library.

Libraries are screened with probes or analytical tools designed to identify the gene of interest or the protein encoded by it. For cDNA expression libraries, suitable probes include monoclonal or polyclonal antibodies that recognize and specifically bind to HRG; oligonucleotides of about 20-80 bases in length that encode known or suspected portions of



HRG cDNA from the same or different species; and/or complementary or homologous cDNAs or fragments thereof that encode the same or a hybridizing gene. Appropriate probes for screening genomic DNA libraries include, but are not limited to, oligonucleotides; cDNAs or fragments thereof that encode the same or hybridizing DNA; and/or homologous genomic  
5 DNAs or fragments thereof. Screening the cDNA or genomic library with the selected probe may be conducted using standard procedures as described in chapters 10-12 of Sambrook *et al.*, *supra*.

An alternative means to isolate the gene encoding HRG is to use polymerase chain reaction (PCR) methodology as described in section 14 of Sambrook *et al.*, *supra*. This  
10 method requires the use of oligonucleotide probes that will hybridize to HRG. Strategies for selection of oligonucleotides are described below.

Another alternative method for obtaining the gene of interest is to chemically synthesize it using one of the methods described in Engels *et al.* (*Agnew. Chem. Int. Ed. Engl.*,  
28: 716-734, 1989). These methods include triester, phosphite, phosphoramidite and H-  
15 Phosphonate methods, PCR and other autoprimer methods, and oligonucleotide syntheses on solid supports. These methods may be used if the entire nucleic acid sequence of the gene is known, or the sequence of the nucleic acid complementary to the coding strand is available, or alternatively, if the target amino acid sequence is known, one may infer potential nucleic acid sequences using known and preferred coding residues for each amino acid residue.

20 A preferred method of practicing this invention is to use carefully selected oligonucleotide sequences to screen cDNA libraries from various tissues, preferably human breast, colon, salivary gland, placental, fetal, brain, and carcinoma cell lines. Other biological sources of DNA encoding an heregulin-like ligand include other mammals and birds. Among the preferred mammals are members of the following orders: bovine, ovine, equine, murine, and  
25 rodentia.

The oligonucleotide sequences selected as probes should be of sufficient length and sufficiently unambiguous that false positives are minimized. The actual nucleotide sequence(s) is usually based on conserved or highly homologous nucleotide sequences or regions of HRG- $\alpha$ . The oligonucleotides may be degenerate at one or more positions. The use  
30 of degenerate oligonucleotides may be of particular importance where a library is screened from a species in which preferential codon usage in that species is not known. The oligonucleotide must be labeled such that it can be detected upon hybridization to DNA in the library being screened. The preferred method of labeling is to use  $^{32}\text{P}$ -labeled ATP with polynucleotide kinase, as is well known in the art, to radiolabel the oligonucleotide. However,  
35 other methods may be used to label the oligonucleotide, including, but not limited to, biotinylation or enzyme labeling.

Of particular interest is HRG nucleic acid that encodes the full-length propolypeptide. In some preferred embodiments, the nucleic acid sequence includes the native HRG signal transmembrane sequence. Nucleic acid having all the protein coding sequence is obtained by

screening selected cDNA or genomic libraries, and, if necessary, using conventional primer extension procedures as described in section 7.79 of Sambrook *et al.*, *supra*, to detect precursors and processing intermediates of mRNA that may not have been reverse-transcribed into cDNA.

- 5 HRG encoding DNA is used to isolate DNA encoding the analogous ligand from other animal species via hybridization employing the methods discussed above. The preferred animals are mammals, particularly bovine, ovine, equine, feline, canine and rodentia, and more specifically rats, mice and rabbits.

#### **B. Amino Acid Sequence Variants of Heregulin**

- 10 Amino acid sequence variants of HRG are prepared by introducing appropriate nucleotide changes into HRG DNA, or by *in vitro* synthesis of the desired HRG polypeptide. Such variants include, for example, deletions from, or insertions or substitutions of, residues within the amino acid sequence shown for human HRG sequences. Any combination of deletion, insertion, and substitution can be made to arrive at the final construct, provided that
- 15 the final construct possesses the desired characteristics. The amino acid changes also may alter post-translational processes of HRG- $\alpha$ , such as changing the number or position of glycosylation sites, altering the membrane anchoring characteristics, altering the intra-cellular location of HRG by inserting, deleting, or otherwise affecting the transmembrane sequence of native HRG, or modifying its susceptibility to proteolytic cleavage.

- 20 In designing amino acid sequence variants of HRG, the location of the mutation site and the nature of the mutation will depend on HRG characteristic(s) to be modified. The sites for mutation can be modified individually or in series, e.g., by (1) substituting first with conservative amino acid choices and then with more radical selections depending upon the results achieved, (2) deleting the target residue, or (3) inserting residues of other ligands
- 25 adjacent to the located site.

- A useful method for identification of HRG residues or regions for mutagenesis is called "alanine scanning mutagenesis" as described by Cunningham and Wells (*Science*, 244: 1081-1085, 1989). Here, a residue or group of target residues are identified (e.g., charged residues such as arg, asp, his, lys, and glu) and replaced by a neutral or negatively charged amino acid
- 30 (most preferably alanine or polyalanine) to affect the interaction of the amino acids with the surrounding aqueous environment in or outside the cell. Those domains demonstrating functional sensitivity to the substitutions then are refined by introducing further or other variants at or for the sites of substitution. Thus, while the site for introducing an amino acid sequence variation is predetermined, the nature of the mutation *per se* need not be
- 35 predetermined. For example, to optimize the performance of a mutation at a given site, ala scanning or random mutagenesis may be conducted at the target codon or region and the expressed HRG variants are screened for the optimal combination of desired activity.

There are two principal variables in the construction of amino acid sequence variants: the location of the mutation site and the nature of the mutation. These are variants from

HRG sequence, and may represent naturally occurring alleles (which will not require manipulation of HRG DNA) or predetermined mutant forms made by mutating the DNA, either to arrive at an allele or a variant not found in nature. In general, the location and nature of the mutation chosen will depend upon HRG characteristic to be modified. Obviously, such variations that, for example, convert HRG into a known receptor ligand, are not included within the scope of this invention, nor are any other HRG variants or polypeptide sequences that are not novel and unobvious over the prior art.

Amino acid sequence deletions generally range from about 1 to 30 residues, more preferably about 1 to 10 residues, and typically about 1 to 5 contiguous residues. Deletions may be introduced into regions of low homology with other EGF family precursors to modify the activity of HRG. Deletions from HRG in areas of substantial homology with other EGF family sequences will be more likely to modify the biological activity of HRG more significantly. The number of consecutive deletions will be selected so as to preserve the tertiary structure of HRG in the affected domain, e.g., cysteine crosslinking, beta-pleated sheet or alpha helix.

Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence insertions of single or multiple amino acid residues. Intrasequence insertions (i.e., insertions within HRG sequence) may range generally from about 1 to 10 residues, more preferably 1 to 5, and most preferably 1 to 3. Examples of terminal insertions include HRG with an N-terminal methionyl residue (an artifact of the direct expression of HRG in bacterial recombinant cell culture), and fusion of a heterologous N-terminal signal sequence to the N-terminus of HRG to facilitate the secretion of mature HRG from recombinant host cells. Such signal sequences generally will be obtained from, and thus be homologous to, the intended host cell species. Suitable sequences include STII or lpp for *E. coli*, alpha factor for yeast, and viral signals such as herpes gD for mammalian cells.

Other insertional variants of HRG include the fusion to the N- or C-terminus of HRG to an immunogenic polypeptide, e.g., bacterial polypeptides such as beta-lactamase or an enzyme encoded by the *E. coli trp* locus, or yeast protein, bovine serum albumin, and chemotactic polypeptides. C-terminal fusions of HRG-NTD-GFD with proteins having a long half-life such as immunoglobulin constant regions (or other immunoglobulin regions), albumin, or ferritin, as described in WO 89/02922, published 6 April 1989 are included.

Another group of variants are amino acid substitution variants. These variants have at least one amino acid residue in the HRG molecule removed and a different residue inserted in its place. The sites of greatest interest for substitutional mutagenesis include sites identified as the active site(s) of HRG, and sites where the amino acids found in HRG ligands from various species are substantially different in terms of side-chain bulk, charge, and/or hydrophobicity.

The amino terminus of the cytoplasmic region of HRG may be fused to the carboxy terminus of heterologous transmembrane domains and receptors, to form a fusion polypeptide useful for intracellular signaling of a ligand binding to the heterologous receptor.

Other sites of interest are those in which particular residues of HRG-like ligands obtained from various species are identical. These positions may be important for the biological activity of HRG. These sites, especially those falling within a sequence of at least three other identically conserved sites, are substituted in a relatively conservative manner. Such conservative substitutions are shown in Table 1 under the heading of "preferred substitutions". If such substitutions result in a change in biological activity, then more substantial changes, denominated exemplary substitutions in Table 1, or as further described below in reference to amino acid classes, are introduced and the products screened.

TABLE 1

	Original Residue	Exemplary Substitutions	Preferred Substitutions
15	Ala (A)	val; leu; ile	val
	Arg (R)	lys; gln; asn	lys
	Asn (N)	gln; his; lys; arg	gln
	Asp (D)	glu	glu
20	Cys (C)	ser	ser
	Gln (Q)	asn	asn
	Glu (E)	asp	asp
	Gly (G)	pro	pro
	His (H)	asn; gln; lys; arg	arg
25	Ile (I)	leu; val; met; ala; phe; norleucine	leu
	Leu (L)	norleucine; ile; val; met; ala; phe	ile
	Lys (K)	arg; gln; asn	arg
30	Met (M)	leu; phe; ile	leu
	Phe (F)	leu; val; ile; ala	leu
	Pro (P)	gly	gly
	Ser (S)	thr	thr
	Thr (T)	ser	ser
35	Trp (W)	tyr	tyr
	Tyr (Y)	trp; phe; thr; ser	phe
	Val (V)	ile; leu; met; phe; ala; norleucine	leu

Substantial modifications in function or immunological identity of HRG are accomplished by selecting substitutions that differ significantly in their effect on maintaining (a) the structure of the polypeptide backbone in the area of the substitution, for example, as a sheet or helical conformation, (b) the charge or hydrophobicity of the molecule at the target site, or (c) the bulk of the side chain. Naturally occurring residues are divided into groups based on common side chain properties:

- 1) hydrophobic: norleucine, met, ala, val, leu, ile;
- 2) neutral hydrophilic: cys, ser, thr;
- 3) acidic: asp, glu;
- 10 4) basic: asn, gln, his, lys, arg;
- 5) residues that influence chain orientation: gly, pro; and
- 6) aromatic: trp, tyr, phe.

Non-conservative substitutions will entail exchanging a member of one of these classes for another. Such substituted residues may be introduced into regions of HRG that are homologous with other receptor ligands, or, more preferably, into the non-homologous regions of the molecule.

In one embodiment of the invention, it is desirable to inactivate one or more protease cleavage sites that are present in the molecule. These sites are identified by inspection of the encoded amino acid sequence. Where potential protease cleavage sites are identified, e.g. at K241 R242, they are rendered inactive to proteolytic cleavage by substituting the targeted residue with another residue, preferably a basic residue such as glutamine or a hydrophilic residue such as serine; by deleting the residue; or by inserting a prolyl residue immediately after the residue.

In another embodiment, any methionyl residue other than the starting methionyl residue, or any residue located within about three residues N- or C-terminal to each such methionyl residue, is substituted by another residue (preferably in accord with Table 1) or deleted. We have found that oxidation of the 2 GFD M residues in the courses of *E. coli* expression appears to severely reduce GFD activity. Thus, these M residues are mutated in accord with Table 1. Alternatively, about 1-3 residues are inserted adjacent to such sites.

Any cysteine residues not involved in maintaining the proper conformation of HRG also may be substituted, generally with serine, to improve the oxidative stability of the molecule and prevent aberrant crosslinking.

Sites particularly suited for substitutions, deletions or insertions, or use as fragments, include, numbered from the N-terminus of HRG- $\alpha$  of Figure 4:

- 35 1) potential glycosaminoglycan addition sites at the serine-glycine dipeptides at 42-43, 64-65, 151-152;
- 2) potential asparagine-linked glycosylation at positions 164, 170, 208 and 437, sites (NDS) 164-166, (NIT) 170-172, (NTS) 208-210, and NTS (609-611);
- 3) potential O-glycosylation in a cluster of serine and threonine at 209-218;

- 4) cysteines at 226, 234, 240, 254, 256 and 265;
- 5) transmembrane domain at 287-309;
- 6) loop 1 delineated by cysteines 226 and 240;
- 7) loop 2 delineated by cysteines 234 and 254;
- 5 8) loop 3 delineated by cysteines 256 and 265; and
- 9) potential protease processing sites at 2-3, 8-9, 23-24, 33-34, 36-37, 45-46, 48-49, 62-63, 66-67, 86-87, 110-111, 123-124, 134-135, 142-143, 272-273, 278-279 and 285-286;

Analogous regions in HRG- $\beta$ 1 may be determined by reference to figure 9 which aligns analogous amino acids in HRG- $\alpha$  and HRG- $\beta$ 1. The analogous HRG- $\beta$ 1 amino acids may be mutated or modified as discussed above for HRG- $\alpha$ . Analogous regions in HRG- $\beta$ 2 may be determined by reference to figure 15 which aligns analogous amino acids in HRG- $\alpha$ , HRG- $\beta$ 1 and HRG- $\beta$ 2. The analogous HRG- $\beta$ 2 amino acids may be mutated or modified as discussed above for HRG- $\alpha$  or HRG- $\beta$ 1. Analogous regions in HRG- $\beta$ 3 may be determined by reference to figure 15 which aligns analogous amino acids in HRG- $\alpha$ , HRG- $\beta$ 1 and HRG- $\beta$ 2. The analogous HRG- $\beta$ 3 amino acids may be mutated or modified as discussed above for HRG- $\alpha$ , HRG- $\beta$ 1, or HRG- $\beta$ 2.

DNA encoding amino acid sequence variants of HRG is prepared by a variety of methods known in the art. These methods include, but are not limited to, isolation from a natural source (in the case of naturally occurring amino acid sequence variants) or preparation by oligonucleotide-mediated (or site-directed) mutagenesis, PCR mutagenesis, and cassette mutagenesis of an earlier prepared variant or a non-variant version of HRG. These techniques may utilize HRG nucleic acid (DNA or RNA), or nucleic acid complementary to HRG nucleic acid.

Oligonucleotide-mediated mutagenesis is a preferred method for preparing substitution, deletion, and insertion variants of HRG DNA. This technique is well known in the art as described by Adelman *et al.*, *DNA*, 2: 183 (1983).

Generally, oligonucleotides of at least 25 nucleotides in length are used. An optimal oligonucleotide will have 12 to 15 nucleotides that are completely complementary to the template on either side of the nucleotide(s) coding for the mutation. This ensures that the oligonucleotide will hybridize properly to the single-stranded DNA template molecule. The oligonucleotides are readily synthesized using techniques known in the art such as that described by Crea *et al.* (*Proc. Natl. Acad. Sci. USA*, 75: 5765, 1978).

Single-stranded DNA template may also be generated by denaturing double-stranded plasmid (or other) DNA using standard techniques.

For alteration of the native DNA sequence (to generate amino acid sequence variants, for example), the oligonucleotide is hybridized to the single-stranded template under suitable hybridization conditions. A DNA polymerizing enzyme, usually the Klenow fragment of DNA polymerase I, is then added to synthesize the complementary strand of the template using the oligonucleotide as a primer for synthesis. A heteroduplex molecule is thus formed

such that one strand of DNA encodes the mutated form of HRG, and the other strand (the original template) encodes the native, unaltered sequence of HRG. This heteroduplex molecule is then transformed into a suitable host cell, usually a prokaryote such as *E. coli* JM101. After the cells are grown, they are plated onto agarose plates and screened using the oligonucleotide primer radiolabeled with  $^{32}\text{P}$ -phosphate to identify the bacterial colonies that contain the mutated DNA. The mutated region is then removed and placed in an appropriate vector for protein production, generally an expression vector of the type typically employed for transformation of an appropriate host.

The method described immediately above may be modified such that a homoduplex molecule is created wherein both strands of the plasmid contain the mutation(s). The modifications are as follows: the single-stranded oligonucleotide is annealed to the single-stranded template as described above. A mixture of three deoxyribonucleotides, deoxyriboadenosine (dATP), deoxyriboguanosine (dGTP), and deoxyribothymidine (dTTP), is combined with a modified thio-deoxyribocytosine called dCTP-(aS) (Amersham Corporation). This mixture is added to the template-oligonucleotide complex. Upon addition of DNA polymerase to this mixture, a strand of DNA identical to the template except for the mutated bases is generated. In addition, this new strand of DNA will contain dCTP-(aS) instead of dCTP, which serves to protect it from restriction endonuclease digestion. After the template strand of the double-stranded heteroduplex is nicked with an appropriate restriction enzyme, the template strand can be digested with ExoIII nuclease or another appropriate nuclease past the region that contains the site(s) to be mutagenized. The reaction is then stopped to leave a molecule that is only partially single-stranded. A complete double-stranded DNA homoduplex is then formed using DNA polymerase in the presence of all four deoxyribonucleotide triphosphates, ATP, and DNA ligase. This homoduplex molecule can then be transformed into a suitable host cell such as *E. coli* JM101, as described above.

Explanatory substitutions common to any HRG include S2T or D; E3D or K; R4 K or E; K5R or E; E6D or K; G7P or Y; R8K or D; G9P or Y; K10R or E; G11P or Y; K12R or E; G19P or Y; S20T or F; G21P or Y; K22 or E; K23R or E; Q38D; S107N; G108P; N120K; D121K; S122 T; N126S; I126L; T127S; A163V; N164K; T165-T174; any residue to I, L, V, M, F, D, E, R or K; G175V or P; T176S or V; S177K or T; H178K or S; L179F or I; V180L or S; K181R or E; A183N or V; E184K or D; K185R or E; E186D or Y; K187R or D; T188S or Q; F189Y or S; V191L or D; N192Q or H; G193P or A; G194P or A; E195D or K; F197Y or I; M198V or Y; V199L or T; K200V or R; D201E or K; L202E or K; S203A or T; N204Δ; N204Q; P205Δ; P205G; S206T or R; R207K or A; Y208P or F; L209I or D; K211I or D; F216Y or I; T217 H or S; G218A or P; A/D219K or R; R220K or A; A235/240/232V or F; E236/241/233D or K; E237/242/234D or K; L238/243/235I or T; Y239/244/236F or T; Q240/245/237N or K; K241/246/238H or R; R242/247/238H or K; V243/248/239L or T; L244/249/240I or S; T245/250/241S or I; I246/251/242V or T and T247/252/243S or I. Specifically with respect to HRG-α, T222S, K or V; E223D, R or Q; N224Q, K or F; V225A, R or D; P226G, I K or F; M227V, T, R or Y;

K228R, H or D; V229L, K or D; Q230N, R or Y; N231Q, K or Y; Q232N, R or Y; E233D, K or T and K 234R, H or D (adjacent K/R mutations are paired in alternative embodiments to create new proteolysis sites). Specifically with respect to HRG- $\beta$  (any member), Q222N, R or Y; N223Q, K or Y; Y224F, T or R; V225A, K or D; M226V, T or R; A227V, K, Y or D; 5 S228T, Y or R; F229Y, I or K and Y230F, T or R are suitable variants. Specifically with respect to HRG- $\beta_1$ , K231R or D, H232R or D; L233I, K, F or Y; G234P, R, A or S; I235I, K, F or Y; E236D, R or A; F237I, Y, K or A; M238V, T, R or A and E239D, R or A are suitable variants. Specifically with respect to HRG- $\beta_1$  and HRG- $\beta_2$ , K231R or D are suitable variants. Alternatively, each of these residues may be deleted or the indicated substituents 10 inserted adjacent thereto. In addition, about from 1-10 variants are combined to produce combinations. These changes are made in the proHRG, NTD, GFD, NTD-GFD or other fragments or fusions. Q213-G215, A219 and the about 11-21 residues C-terminal to C221 differ among the various HRG classes. Residues at these are interchanged among HRG classes or EGF family members, are deleted, or a residue inserted adjacent thereto.

15 DNA encoding HRG- $\alpha$  mutants with more than one amino acid to be substituted may be generated in one of several ways. If the amino acids are located close together in the polypeptide chain, they may be mutated simultaneously using one oligonucleotide that codes for all of the desired amino acid substitutions. If, however, the amino acids are located some distance from each other (separated by more than about ten amino acids), it is more difficult 20 to generate a single oligonucleotide that encodes all of the desired changes. Instead, one of two alternative methods may be employed.

PCR mutagenesis is also suitable for making amino acid variants of HRG- $\alpha$ . While the following discussion refers to DNA, it is understood that the technique also finds application with RNA. The PCR technique generally refers to the following procedure (see 25 Erlich, *supra*, the chapter by R. Higuchi, p. 61-70). When small amounts of template DNA are used as starting material in a PCR, primers that differ slightly in sequence from the corresponding region in a template DNA can be used to generate relatively large quantities of a specific DNA fragment that differs from the template sequence only at the positions where the primers differ from the template. For introduction of a mutation into a plasmid DNA, one 30 of the primers is designed to overlap the position of the mutation and to contain the mutation; the sequence of the other primer must be identical to a stretch of sequence of the opposite strand of the plasmid, but this sequence can be located anywhere along the plasmid DNA. It is preferred, however, that the sequence of the second primer is located within 200 nucleotides from that of the first, such that in the end the entire amplified region of DNA bounded by the 35 primers can be easily sequenced. PCR amplification using a primer pair like the one just described results in a population of DNA fragments that differ at the position of the mutation specified by the primer, and possibly at other positions, as template copying is somewhat error-prone.



If the ratio of template to product material is extremely low, the vast majority of product DNA fragments incorporate the desired mutation(s). This product material is used to replace the corresponding region in the plasmid that served as PCR template using standard DNA technology. Mutations at separate positions can be introduced simultaneously by either  
5 using a mutant second primer, or performing a second PCR with different mutant primers and ligating the two resulting PCR fragments simultaneously to the vector fragment in a three (or more)-part ligation.

Another method for preparing variants, cassette mutagenesis, is based on the technique described by Wells *et al.* (*Gene*, 34: 315, 1985). The starting material is the plasmid  
10 (or other vector) comprising HRG DNA to be mutated. The codon(s) in HRG DNA to be mutated are identified. There must be a unique restriction endonuclease site on each side of the identified mutation site(s). If no such restriction sites exist, they may be generated using the above-described oligonucleotide-mediated mutagenesis method to introduce them at appropriate locations in HRG DNA. After the restriction sites have been introduced into the  
15 plasmid, the plasmid is cut at these sites to linearize it. A double-stranded oligonucleotide encoding the sequence of the DNA between the restriction sites but containing the desired mutation(s) is synthesized using standard procedures. The two strands are synthesized separately and then hybridized together using standard techniques. This double-stranded oligonucleotide is referred to as the cassette. This cassette is designed to have 3' and 5' ends  
20 that are compatible with the ends of the linearized plasmid, such that it can be directly ligated to the plasmid. This plasmid now contains the mutated HRG DNA sequence.

### C. Insertion of DNA into a Cloning or Expression Vehicle

The cDNA or genomic DNA encoding native or variant HRG is inserted into a replicable vector for further cloning (amplification of the DNA) or for expression. Many  
25 vectors are available, and selection of the appropriate vector will depend on 1) whether it is to be used for DNA amplification or for DNA expression, 2) the size of the DNA to be inserted into the vector, and 3) the host cell to be transformed with the vector. Each vector contains various components depending on its function (amplification of DNA or expression of DNA) and the host cell for which it is compatible. The vector components generally include, but are  
30 not limited to, one or more of the following: a signal sequence, an origin of replication, one or more marker genes, an enhancer element, a promoter, and a transcription termination sequence.

#### (I) Signal Sequence Component

In general, the signal sequence may be a component of the vector, or it may be a part  
35 of HRG DNA that is inserted into the vector. The native HRG DNA is believed to encode a signal sequence at the amino terminus (5' end of the DNA encoding HRG) of the polypeptide that is cleaved during post-translational processing of the polypeptide to form the mature HRG polypeptide ligand that binds to p185<sup>HER2</sup> receptor, although a conventional signal structure is not apparent. Native proHRG is secreted from the cell but may remain lodged in

the membrane because it contains a transmembrane domain and a cytoplasmic region in the carboxyl terminal region of the polypeptide. Thus, in a secreted, soluble version of HRG the carboxyl terminal domain of the molecule, including the transmembrane domain, is ordinarily deleted. This truncated variant HRG polypeptide may be secreted from the cell, provided that  
5 the DNA encoding the truncated variant encodes a signal sequence recognized by the host.

HRG of this invention may be expressed not only directly, but also as a fusion with a heterologous polypeptide, preferably a signal sequence or other polypeptide having a specific cleavage site at the N-and/or C-terminis of the mature protein or polypeptide. In general, the signal sequence may be a component of the vector, or it may be a part of HRG DNA that is  
10 inserted into the vector. Included within the scope of this invention are HRG with the native signal sequence deleted and replaced with a heterologous signal sequence. The heterologous signal sequence selected should be one that is recognized and processed, i.e., cleaved by a signal peptidase, by the host cell. For prokaryotic host cells that do not recognize and process the native HRG signal sequence, the signal sequence is substituted by a prokaryotic  
15 signal sequence selected, for example, from the group of the alkaline phosphatase, penicillinase, lpp, or heat-stable enterotoxin II leaders. For yeast secretion the native HRG signal sequence may be substituted by the yeast invertase, alpha factor, or acid phosphatase leaders. In mammalian cell expression the native signal sequence is satisfactory, although other mammalian signal sequences may be suitable.

#### 20 (ii) Origin of Replication Component

Both expression and cloning vectors generally contain a nucleic acid sequence that enables the vector to replicate in one or more selected host cells. Generally, in cloning vectors this sequence is one that enables the vector to replicate independently of the host chromosomal DNA, and includes origins of replication or autonomously replicating sequences.  
25 Such sequences are well known for a variety of bacteria, yeast, and viruses. The origin of replication from the plasmid pBR322 is suitable for most Gram-negative bacteria, the 2 $\mu$  plasmid origin is suitable for yeast, and various viral origins (SV40, polyoma, adenovirus, VSV or BPV) are useful for cloning vectors in mammalian cells. Generally, the origin of replication component is not needed for mammalian expression vectors (the SV40 origin may  
30 typically be used only because it contains the early promoter).

Most expression vectors are "shuttle" vectors, i.e., they are capable of replication in at least one class of organisms but can be transfected into another organism for expression. For example, a vector is cloned in *E. coli* and then the same vector is transfected into yeast or mammalian cells for expression even though it is not capable of replicating independently of  
35 the host cell chromosome.

DNA may also be amplified by insertion into the host genome. This is readily accomplished using *Bacillus* species as hosts, for example, by including in the vector a DNA sequence that is complementary to a sequence found in *Bacillus* genomic DNA. Transfection of *Bacillus* with this vector results in homologous recombination with the genome and insertion

of HRG DNA. However, the recovery of genomic DNA encoding HRG is more complex than that of an exogenously replicated vector because restriction enzyme digestion is required to excise HRG DNA. DNA can be amplified by PCR and directly transfected into the host cells without any replication component.

5                                    (iii) Selection Gene Component

Expression and cloning vectors should contain a selection gene, also termed a selectable marker. This gene encodes a protein necessary for the survival or growth of transformed host cells grown in a selective culture medium. Host cells not transformed with the vector containing the selection gene will not survive in the culture medium. Typical  
10 selection genes encode proteins that (a) confer resistance to antibiotics or other toxins, e.g., ampicillin, neomycin, methotrexate, or tetracycline, (b) complement auxotrophic deficiencies, or (c) supply critical nutrients not available from complex media, e.g., the gene encoding D-alanine racemase for *Bacilli*.

One example of a selection scheme utilizes a drug to arrest growth of a host cell.  
15 Those cells that are successfully transformed with a heterologous gene express a protein conferring drug resistance and thus survive the selection regimen. Examples of such dominant selection use the drugs neomycin (Southern *et al.*, *J. Molec. Appl. Genet.* 1: 327,1982), mycophenolic acid (Mulligan *et al.*, *Science* 209: 1422,1980) or hygromycin (Sugden *et al.*, *Mol. Cell. Biol.* 5: 410-413,1985). The three examples given above employ bacterial genes under  
20 eukaryotic control to convey resistance to the appropriate drug G418 or neomycin (geneticin), xgpt (mycophenolic acid), or hygromycin, respectively.

Another example of suitable selectable markers for mammalian cells are those that enable the identification of cells competent to take up HRG nucleic acid, such as dihydrofolate reductase (DHFR) or thymidine kinase. The mammalian cell transformants are placed under  
25 selection pressure which only the transformants are uniquely adapted to survive by virtue of having taken up the marker. Selection pressure is imposed by culturing the transformants under conditions in which the concentration of selection agent in the medium is successively changed, thereby leading to amplification of both the selection gene and the DNA that encodes HRG. Amplification is the process by which genes in greater demand for the production of a  
30 protein critical for growth are reiterated in tandem within the chromosomes of successive generations of recombinant cells. Increased quantities of HRG are synthesized from the amplified DNA.

For example, cells transformed with the DHFR selection gene are first identified by culturing all of the transformants in a culture medium that contains methotrexate (Mtx), a  
35 competitive antagonist of DHFR. An appropriate host cell when wild-type DHFR is employed is the Chinese hamster ovary (CHO) cell line deficient in DHFR activity, prepared and propagated as described by Urlaub and Chasin, *Proc. Natl. Acad. Sci. USA*, 77: 4216, 1980. The transformed cells are then exposed to increased levels of methotrexate. This leads to the synthesis of multiple copies of the DHFR gene, and, concomitantly, multiple copies of other

DNA comprising the expression vectors, such as the DNA encoding HRG. This amplification technique can be used with any otherwise suitable host, e.g., ATCC No. CCL61 CHO-K1, notwithstanding the presence of endogenous DHFR if, for example, a mutant DHFR gene that is highly resistant to Mtx is employed (EP 117,060). Alternatively, host cells (particularly  
5 wild-type hosts that contain endogenous DHFR) transformed or co-transformed with DNA sequences encoding HRG, wild-type DHFR protein, and another selectable marker such as aminoglycoside 3' phosphotransferase (APH) can be selected by cell growth in medium containing a selection agent for the selectable marker such as an aminoglycosidic antibiotic, e.g., kanamycin, neomycin, or G418 (see U.S. Pat. No. 4,965,199).

10 A suitable selection gene for use in yeast is the *trp1* gene present in the yeast plasmid YRp7 (Stinchcomb *et al.*, *Nature*, 282: 39, 1979; Kingsman *et al.*, *Gene*, 7: 141, 1979; or Tschemper *et al.*, *Gene*, 10: 157, 1980). The *trp1* gene provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan, for example, ATCC No. 44076 or PEP4-1 (Jones, *Genetics*, 85: 12, 1977). The presence of the *trp1* lesion in the yeast  
15 host cell genome then provides an effective environment for detecting transformation by growth in the absence of tryptophan. Similarly, *Leu2*-deficient yeast strains (ATCC 20,622 or 38,626) are complemented by known plasmids bearing the *Leu2* gene.

#### (iv) Promoter Component

Expression and cloning vectors usually contain a promoter that is recognized by the  
20 host organism and is operably linked to HRG nucleic acid. Promoters are untranslated sequences located upstream (5') to the start codon of a structural gene (generally within about 100 to 1000 bp) that control the transcription and translation of a particular nucleic acid sequence, such as HRG to which they are operably linked. Such promoters typically fall into two classes, inducible and constitutive. Inducible promoters are promoters that initiate  
25 increased levels of transcription from DNA under their control in response to some change in culture conditions, e.g., the presence or absence of a nutrient or a change in temperature. At this time a large number of promoters recognized by a variety of potential host cells are well known. These promoters are operably linked to DNA encoding HRG by removing the promoter from the source DNA by restriction enzyme digestion and inserting the isolated promoter  
30 sequence into the vector. Both the native HRG promoter sequence and many heterologous promoters may be used to direct amplification and/or expression of HRG DNA. However, heterologous promoters are preferred, as they generally permit greater transcription and higher yields of expressed HRG as compared to the native HRG promoter.

Promoters suitable for use with prokaryotic hosts include the  $\beta$ -lactamase and  
35 lactose promoter systems (Chang *et al.*, *Nature*, 275: 615, 1978; and Goeddel *et al.*, *Nature* 281: 544, 1979), alkaline phosphatase, a tryptophan (*trp*) promoter system (Goeddel, *Nucleic Acids Res.*, 8: 4057, 1980 and EP 36,776) and hybrid promoters such as the *tac* promoter (deBoer *et al.*, *Proc. Natl. Acad. Sci. USA* 80: 21-25, 1983). However, other known bacterial promoters are suitable. Their nucleotide sequences have been published, thereby enabling a

skilled worker operably to ligate them to DNA encoding HRG (Siebenlist *et al.*, *Cell* 20: 269, 1980) using linkers or adaptors to supply any required restriction sites. Promoters for use in bacterial systems also generally will contain a Shine-Dalgarno (S.D.) sequence operably linked to the DNA encoding HRG.

5        Suitable promoting sequences for use with yeast hosts include the promoters for 3-phosphoglycerate kinase (Hitzeman *et al.*, *J. Biol. Chem.*, 255: 2073, 1980) or other glycolytic enzymes (Hess *et al.*, *J. Adv. Enzyme Reg* 7: 149, 1968; and Holland, *Biochemistry* 17: 4900, 1978), such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate  
10        mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase, and glucokinase.

Other yeast promoters, which are inducible promoters having the additional advantage of transcription controlled by growth conditions, are the promoter regions for alcohol dehydrogenase 2, isocytochrome C, acid phosphatase, degradative enzymes  
15        associated with nitrogen metabolism, metallothionein, glyceraldehyde-3-phosphate dehydrogenase, and enzymes responsible for maltose and galactose utilization. Suitable vectors and promoters for use in yeast expression are further described in Hitzeman *et al.*, EP 73,657A. Yeast enhancers also are advantageously used with yeast promoters.

Promoter sequences are known for eukaryotes. Virtually all eukaryotic genes have  
20        an AT-rich region located approximately 25 to 30 bases upstream from the site where transcription is initiated. Another sequence found 70 to 80 bases upstream from the start of transcription of many genes is a CXCAAT (SEQ ID NO:1) region where X may be any nucleotide. At the 3' end of most eukaryotic genes is an AATAAA sequence (SEQ ID NO:2) that may be the signal for addition of the poly A tail to the 3' end of the coding sequence. All  
25        of these sequences are suitably inserted into mammalian expression vectors.

HRG gene transcription from vectors in mammalian host cells is controlled by promoters obtained from the genomes of viruses such as polyoma virus, fowlpox virus (UK 2,211,504, published 5 July 1989), adenovirus (such as Adenovirus 2), bovine papilloma virus, avian sarcoma virus, cytomegalovirus, a retrovirus, hepatitis-B virus and most preferably  
30        Simian Virus 40 (SV40), from heterologous mammalian promoters, e.g., the actin promoter or an immunoglobulin promoter, from heat-shock promoters, and from the promoter normally associated with HRG sequence, provided such promoters are compatible with the host cell systems.

The early and late promoters of the SV40 virus are conveniently obtained as an  
35        SV40 restriction fragment that also contains the SV40 viral origin of replication (Fiers *et al.*, *Nature*, 273:113 (1978); Mulligan and Berg, *Science*, 209: 1422-1427 (1980); Pavlakis *et al.*, *Proc. Natl. Acad. Sci. USA*, 78: 7398-7402 (1981)). The immediate early promoter of the human cytomegalovirus is conveniently obtained as a HindIII E restriction fragment (Greenaway *et al.*, *Gene*, 18: 355-360 (1982)). A system for expressing DNA in mammalian

hosts using the bovine papilloma virus as a vector is disclosed in U.S. Pat. No. 4,419,446. A modification of this system is described in U.S. Pat. No. 4,601,978. See also Gray *et al.*, *Nature*, 295: 503-508 (1982) on expressing cDNA encoding immune interferon in monkey cells; Reyes *et al.*, *Nature*, 297: 598-601 (1982) on expression of human  $\beta$ -interferon cDNA in mouse cells under the control of a thymidine kinase promoter from herpes simplex virus; Canaani and Berg, *Proc. Natl. Acad. Sci. USA*, 79: 5166-5170 (1982) on expression of the human interferon  $\beta$ 1 gene in cultured mouse and rabbit cells; and Gorman *et al.*, *Proc. Natl. Acad. Sci. USA*, 79: 6777-6781 (1982) on expression of bacterial CAT sequences in CV-1 monkey kidney cells, chicken embryo fibroblasts, Chinese hamster ovary cells, HeLa cells, and mouse NIH-3T3 cells using the Rous sarcoma virus long terminal repeat as a promoter.

#### (v) Enhancer Element Component

Transcription of a DNA encoding HRG of this invention by higher eukaryotes is often increased by inserting an enhancer sequence into the vector. Enhancers are cis-acting elements of DNA, usually about from 10-300 bp, that act on a promoter to increase its transcription. Enhancers are relatively orientation and position independent having been found 5' (Laimins *et al.*, *Proc. Natl. Acad. Sci. USA*, 78: 993, 1981) and 3' (Lusky *et al.*, *Mol. Cell Bio.*, 3: 1108, 1983) to the transcription unit, within an intron (Banerji *et al.*, *Cell*, 33: 729, 1983) as well as within the coding sequence itself (Osborne *et al.*, *Mol. Cell Bio.*, 4: 1293, 1984). Many enhancer sequences are now known from mammalian genes (globin, elastase, albumin,  $\alpha$ -fetoprotein and insulin). Typically, however, one will use an enhancer from a eukaryotic cell virus. Examples include the SV40 enhancer on the late side of the replication origin (bp 100-270), the cytomegalovirus early promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers (see also Yaniv, *Nature*, 297: 17-18 (1982)) on enhancing elements for activation of eukaryotic promoters. The enhancer may be spliced into the vector at a position 5' or 3' to HRG DNA, but is preferably located at a site 5' from the promoter.

#### (vi) Transcription Termination Component

Expression vectors used in eukaryotic host cells (yeast, fungi, insect, plant, animal, human, or nucleated cells from other multicellular organisms) will also contain sequences necessary for the termination of transcription and for stabilizing the mRNA. Such sequences are commonly available from the 5' and, occasionally 3' untranslated regions of eukaryotic or viral DNAs or cDNAs. These regions contain nucleotide segments transcribed as polyadenylated fragments in the untranslated portion of the mRNA encoding HRG. The 3' untranslated regions also include transcription termination sites.

Construction of suitable vectors containing one or more of the above listed components the desired coding and control sequences employs standard ligation techniques. Isolated plasmids or DNA fragments are cleaved, tailored, and religated in the form desired to generate the plasmids required.

For analysis to confirm correct sequences in plasmids constructed, the ligation mixtures are used to transform *E. coli* K12 strain 294 (ATCC 31,446) and successful transformants selected by ampicillin or tetracycline resistance where appropriate. Plasmids from the transformants are prepared, analyzed by restriction endonuclease digestion, and/or  
5 sequenced by the method of Messing *et al.*, *Nucleic Acids Res.* 9: 309 (1981) or by the method of Maxam *et al.*, *Methods in Enzymology* 65: 499 (1980).

Particularly useful in the practice of this invention are expression vectors that provide for the transient expression in mammalian cells of DNA encoding HRG. In general, transient expression involves the use of an expression vector that is able to replicate  
10 efficiently in a host cell, such that the host cell accumulates many copies of the expression vector and, in turn, synthesizes high levels of a desired polypeptide encoded by the expression vector. Transient expression systems, comprising a suitable expression vector and a host cell, allow for the convenient positive identification of polypeptides encoded by cloned DNAs, as well as for the rapid screening of such polypeptides for desired biological or physiological  
15 properties. Thus, transient expression systems are particularly useful in the invention for purposes of identifying analogs and variants of HRG that have HRG-like activity. Such a transient expression system is described in EP 309,237 published 29 March 1989. Other methods, vectors, and host cells suitable for adaptation to the synthesis of HRG in recombinant vertebrate cell culture are described in Gething *et al.*, *Nature* 293: 620-625, 1981;  
20 Mantei *et al.*, *Nature*, 281: 40-46, 1979; Levinson *et al.*, EP 117,060 and EP 117,058. A particularly useful expression plasmid for mammalian cell culture expression of HRG is pRK5 (EP pub. no. 307,247).

#### **D. Selection and Transformation of Host Cells**

Suitable host cells for cloning or expressing the vectors herein are the prokaryote,  
25 yeast, or higher eukaryote cells described above. Suitable prokaryotes include eubacteria, such as Gram-negative or Gram-positive organisms, for example, *E. coli*, *Bacilli* such as *B. subtilis*, *Pseudomonas* species such as *P. aeruginosa*, *Salmonella typhimurium*, or *Serratia marcescans*. One preferred *E. coli* cloning host is *E. coli* 294 (ATCC 31,446), although other strains such as *E. coli* B, *E. coli* x1776 (ATCC 31,537), and *E. coli* W3110 (ATCC 27,325) are  
30 suitable. These examples are illustrative rather than limiting. Preferably the host cell should secrete minimal amounts of proteolytic enzymes. Alternatively, *in vitro* methods of cloning, e.g., PCR or other nucleic acid polymerase reactions, are suitable.

In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable hosts for HRG-encoding vectors. *Saccharomyces cerevisiae*, or common baker's  
35 yeast, is the most commonly used among lower eukaryotic host microorganisms. However, a number of other genera, species, and strains are commonly available and useful herein, such as *Schizosaccharomyces pombe* (Beach and Nurse, *Nature*, 290: 140 (1981); EP 139,383, published May 2, 1985), *Kluyveromyces* hosts (U.S.S.N. 4,943,529) such as, e.g., *K. lactis* (Lourencourt *et al.*, *J. Bacteriol.*, 737 (1983); *K. fragilis*, *K. bulgaricus*, *K. thermotolerans*, and

*K. marxianus*, *yarrowia* (EP 402,226); *Pichia pastoris* (EP 183,070), Sreekrishna *et al.*, *J. Basic Microbiol.*, **28**: 265-278 (1988); *Candida*, *Trichoderma reesia* (EP 244,234); *Neurospora crassa* (Case *et al.*, *Proc. Natl. Acad. Sci. USA*, **76**: 5259-5263 (1979), and filamentous fungi such as, e.g., *Neurospora*, *Penicillium*, *Tolypocladium* (WO 91/00357, published 10 January 1991), and *Aspergillus* hosts such as *A. nidulans* (Ballance *et al.*, *Biochem. Biophys. Res. Commun.*, **112**: 284-289 (1983); Tilburn *et al.*, *Gene*, **26**: 205-221 (1983); Yelton *et al.*, *Proc. Natl. Acad. Sci. USA*, **81**: 1470-1474 (1984) and *A. niger* (Kelly and Hynes, *EMBO J.*, **4**: 475-479 (1985)).

Suitable host cells for the expression of glycosylated HRG polypeptide are derived from multicellular organisms. Such host cells are capable of complex processing and glycosylation activities. In principle, any higher eukaryotic cell culture is workable, whether from vertebrate or invertebrate culture. Examples of invertebrate cells include plant and insect cells. Numerous baculoviral strains and variants and corresponding permissive insect host cells from hosts such as *Spodoptera frugiperda* (caterpillar), *Aedes aegypti* (mosquito), *Aedes albopictus* (mosquito), *Drosophila melanogaster* (fruitfly), and *Bombyx mori* host cells have been identified (see, e.g., Luckow *et al.*, *Bio/Technology*, **6**: 47-55 (1988); Miller *et al.*, in *Genetic Engineering*, Setlow, J.K. *et al.*, eds., Vol. 8 (Plenum Publishing, 1986), pp. 277-279; and Maeda *et al.*, *Nature*, **315**: 592-594 (1985)). A variety of such viral strains are publicly available, e.g., the L-1 variant of *Autographa californica* NPV and the Bm-5 strain of *Bombyx mori* NPV, and such viruses may be used as the virus herein according to the present invention, particularly for transfection of *Spodoptera frugiperda* cells. Plant cell cultures of cotton, corn, potato, soybean, petunia, tomato, and tobacco can be utilized as hosts. Typically, plant cells are transfected by incubation with certain strains of the bacterium *Agrobacterium tumefaciens*, which has been previously manipulated to contain HRG DNA. During incubation of the plant cell culture with *A. tumefaciens*, the DNA encoding HRG is transferred to the plant cell host such that it is transfected, and will, under appropriate conditions, express HRG DNA. In addition, regulatory and signal sequences compatible with plant cells are available, such as the nopaline synthase promoter and polyadenylation signal sequences (Depicker *et al.*, *J. Mol. Appl. Gen.*, **1**:561 [1982]). In addition, DNA segments isolated from the upstream region of the T-DNA 780 gene are capable of activating or increasing transcription levels of plant-expressible genes in recombinant DNA-containing plant tissue (see EP 321,196, published 21 June 1989).

However, interest has been greatest in vertebrate cells, and propagation of vertebrate cells in culture (tissue culture) has become a routine procedure in recent years (*Tissue Culture*, Academic Press, Kruse and Patterson, editors (1973)). Examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-7, ATCC CRL 1651); human embryonic kidney line (293 or 293 cells subcloned for growth in suspension culture, Graham *et al.*, *J. Gen Virol.*, **36**: 59, 1977); baby hamster kidney cells (BHK, ATCC CCL 10); Chinese hamster ovary cells/-DHFR (CHO, Urlaub and Chasin, *Proc. Natl. Acad.*



*Sci. USA*, 77:4216 [1980]); mouse sertoli cells (TM4, Mather, *Biol. Reprod.*, 23:243-251 [1980]); monkey kidney cells (CV1 ATCC CCL 70); African green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HELA, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse mammary tumor (MMT 060562, ATCC CCL51); TRI cells (Mather *et al.*, *Annals N.Y. Acad. Sci.*, 383:44-68 [1982]); MRC 5 cells; FS4 cells; and a human hepatoma cell line (Hep G2). Preferred host cells are human embryonic kidney 293 and Chinese hamster ovary cells.

Host cells are transfected and preferably transformed with the above-described expression or cloning vectors of this invention and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences.

Transfection refers to the taking up of an expression vector by a host cell whether or not any coding sequences are in fact expressed. Numerous methods of transfection are known to the ordinarily skilled artisan, for example,  $\text{CaPO}_4$  and electroporation. Successful transfection is generally recognized when any indication of the operation of this vector occurs within the host cell.

Transformation means introducing DNA into an organism so that the DNA is replicable, either as an extrachromosomal element or by chromosomal integration. Depending on the host cell used, transformation is done using standard techniques appropriate to such cells. The calcium treatment employing calcium chloride, as described in section 1.82 of Sambrook *et al.*, *supra*, is generally used for prokaryotes or other cells that contain substantial cell-wall barriers. Infection with *Agrobacterium tumefaciens* is used for transformation of certain plant cells, as described by Shaw *et al.*, *Gene*, 23: 315 (1983) and WO 89/05859, published 29 June 1989. For mammalian cells without such cell walls, the calcium phosphate precipitation method described in sections 16.30-16.37 of Sambrook *et al.*, *supra*, is preferred. General aspects of mammalian cell host system transformations have been described by Axel in U.S. Pat. No. 4,399,216, issued 16 August 1983. Transformations into yeast are typically carried out according to the method of Van Solingen *et al.*, *J. Bact.*, 130:946 (1977) and Hsiao *et al.*, *Proc. Natl. Acad. Sci. (USA)*, 76: 3829 (1979). However, other methods for introducing DNA into cells such as by nuclear injection, electroporation, or protoplast fusion may also be used.

#### **E. Culturing the Host Cells**

Prokaryotic cells used to produce HRG polypeptide of this invention are cultured in suitable media as described generally in Sambrook *et al.*, *supra*.

The mammalian host cells used to produce HRG of this invention may be cultured in a variety of media. Commercially available media such as Ham's F10 (Sigma), Minimal Essential Medium ([MEM], Sigma), RPMI-1640 (Sigma), and Dulbecco's Modified Eagle's Medium ([DMEM], Sigma) are suitable for culturing the host cells. In addition, any of the media

described in Ham and Wallace, *Meth. Enz.*, 58: 44 (1979), Barnes and Sato, *Anal. Biochem.*, 102:255 (1980), U.S. Pat. Nos. 4,767,704; 4,657,866; 4,927,762; or 4,560,655; WO 90/03430; WO 87/00195 and U.S. Pat. Re. 30,985, may be used as culture media for the host cells. Any of these media may be supplemented as necessary with hormones and/or other growth factors (such as insulin, transferrin, or epidermal growth factor), salts (such as sodium chloride, calcium, magnesium, and phosphate), buffers (such as HEPES), nucleosides (such as adenosine and thymidine), antibiotics (such as Gentamycin<sup>TM</sup> drug), trace elements (defined as inorganic compounds usually present at final concentrations in the micromolar range), and glucose or an equivalent energy source. Any other necessary supplements may also be included at appropriate concentrations that would be known to those skilled in the art. The culture conditions, such as temperature, pH, and the like, are those previously used with the host cell selected for expression, and will be apparent to the ordinarily skilled artisan.

The host cells referred to in this disclosure encompass cells in *in vitro* culture as well as cells that are within a host animal.

It is further envisioned that HRG of this invention may be produced by homologous recombination, or with recombinant production methods utilizing control elements introduced into cells already containing DNA encoding HRG currently in use in the field. For example, a powerful promoter/enhancer element, a suppressor, or an exogenous transcription modulatory element is inserted in the genome of the intended host cell in proximity and orientation sufficient to influence the transcription of DNA encoding the desired HRG. The control element does not encode HRG of this invention, but the DNA is present in the host cell genome. One next screens for cells making HRG of this invention, or increased or decreased levels of expression, as desired.

#### F. Detecting Gene Amplification/Expression

Gene amplification and/or expression may be measured in a sample directly, for example, by conventional Southern blotting, Northern blotting to quantitate the transcription of mRNA (Thomas, *Proc. Natl. Acad. Sci. USA*, 77:5201-5205 [1980]), dot blotting (DNA analysis), or *in situ* hybridization, using an appropriately labeled probe based on the sequences provided herein. Various labels may be employed, most commonly radioisotopes, particularly <sup>32</sup>P. However, other techniques may also be employed, such as using biotin-modified nucleotides for introduction into a polynucleotide. The biotin then serves as the site for binding to avidin or antibodies which may be labeled with a wide variety of labels, such as radionuclides, fluorescers, enzymes, or the like. Alternatively, antibodies may be employed that can recognize specific duplexes, including DNA duplexes, RNA duplexes, and DNA-RNA hybrid duplexes or DNA-protein duplexes. The antibodies in turn may be labeled and the assay may be carried out where the duplex is bound to a surface, so that upon the formation of duplex on the surface, the presence of antibody bound to the duplex can be detected.

Gene expression, alternatively, may be measured by immunological methods, such as immunohistochemical staining of tissue sections and assay of cell culture or body fluids, to

quantitate directly the expression of gene product. With immunohistochemical staining techniques, a cell sample is prepared, typically by dehydration and fixation, followed by reaction with labeled antibodies specific for the gene product coupled where the labels are usually visually detectable such as enzymatic labels, fluorescent labels, luminescent labels, and the like. A particularly sensitive staining technique suitable for use in the present invention is described by Hsu *et al.*, *Am. J. Clin. Path.*, **75**: 734-738 (1980).

Antibodies useful for immunohistochemical staining and/or assay of sample fluids may be either monoclonal or polyclonal, and may be prepared in any mammal. Conveniently, the antibodies may be prepared against a native HRG polypeptide or against a synthetic peptide based on the DNA sequences provided herein as described further in Section 4 below.

#### **G. Purification of The Heregulin Polypeptide**

HRG is recovered from a cellular membrane fraction. Alternatively, a proteolytically cleaved or a truncated expressed soluble HRG fragment or subdomain are recovered from the culture medium as soluble polypeptides.

When HRG is expressed in a recombinant cell other than one of human origin, HRG is completely free of proteins or polypeptides of human origin. However, it is desirable to purify HRG from recombinant cell proteins or polypeptides to obtain preparations that are substantially homogeneous as to HRG. As a first step, the culture medium or lysate is centrifuged to remove particulate cell debris. The membrane and soluble protein fractions are then separated. HRG is then purified from both the soluble protein fraction (requiring the presence of a protease) and from the membrane fraction of the culture lysate, depending on whether HRG is membrane bound. The following procedures are exemplary of suitable purification procedures: fractionation on immunoaffinity or ion-exchange columns; ethanol precipitation; reversed phase HPLC; chromatography on silica, heparin sepharose or on a cation exchange resin such as DEAE; chromatofocusing; SDS-PAGE; ammonium sulfate precipitation; and gel filtration using, for example, Sephadex G-75.

HRG variants in which residues have been deleted, inserted or substituted are recovered in the same fashion as the native HRG, taking account of any substantial changes in properties occasioned by the variation. For example, preparation of a HRG fusion with another protein or polypeptide, e.g., a bacterial or viral antigen, facilitates purification; an immunoaffinity column containing antibody to the antigen can be used to adsorb the fusion. Immunoaffinity columns such as a rabbit polyclonal anti-HRG column can be employed to absorb HRG variant by binding it to at least one remaining immune epitope. A protease inhibitor such as phenylmethylsulfonylfluoride (PMSF) also may be useful to inhibit proteolytic degradation during purification, and antibiotics may be included to prevent the growth of adventitious contaminants. One skilled in the art will appreciate that purification methods suitable for native HRG may require modification to account for changes in the character of HRG variants upon expression in recombinant cell culture.

#### H. Covalent Modifications of HRG

Covalent modifications of HRG polypeptides are included within the scope of this invention. Both native HRG and amino acid sequence variants of HRG optionally are covalently modified. One type of covalent modification included within the scope of this invention is a HRG polypeptide fragment. HRG fragments, such as HRG-GDF, having up to about 40 amino acid residues are conveniently prepared by chemical synthesis, or by enzymatic or chemical cleavage of the full-length HRG polypeptide or HRG variant polypeptide. Other types of covalent modifications of HRG or fragments thereof are introduced into the molecule by reacting targeted amino acid residues of HRG or fragments thereof with an organic derivatizing agent that is capable of reacting with selected side chains or the N- or C-terminal residues.

Cysteinyl residues most commonly are reacted with  $\alpha$ -haloacetates (and corresponding amines), such as chloroacetic acid or chloroacetamide, to give carboxymethyl or carboxyamidomethyl derivatives. Cysteinyl residues also are derivatized by reaction with bromotrifluoroacetone,  $\alpha$ -bromo- $\beta$ -(5-imidazolyl)propionic acid, chloroacetyl phosphate, N-alkylmaleimides, 3-nitro-2-pyridyl disulfide, methyl 2-pyridyl disulfide, p-chloromercuribenzoate, 2-chloromercuri-4-nitrophenol, or chloro-7-nitrobenzo-2-oxa-1,3-diazole.

Histidyl residues are derivatized by reaction with diethylpyrocarbonate at pH 5.5-7.0 because this agent is relatively specific for the histidyl side chain. Para-bromophenacyl bromide also is useful; the reaction is preferably performed in 0.1M sodium cacodylate at pH 6.0.

Lysiny and amino terminal residues are reacted with succinic or other carboxylic acid anhydrides. Derivatization with these agents has the effect of reversing the charge of the lysiny residues. Other suitable reagents for derivatizing  $\alpha$ -amino-containing residues include imidoesters such as methyl picolinimide; pyridoxal phosphate; pyridoxal; chloroborohydride; trinitrobenzenesulfonic acid; O-methylisourea; 2,4-pentanedione; and transaminase-catalyzed reaction with glyoxylate.

Arginy residues are modified by reaction with one or several conventional reagents, among them phenylglyoxal, 2,3-butanedione, 1,2-cyclohexanedione, and ninhydrin. Derivatization of arginine residues requires that the reaction be performed in alkaline conditions because of the high  $pK_a$  of the guanidine functional group. Furthermore, these reagents may react with the groups of lysine as well as the arginine epsilon-amino group.

The specific modification of tyrosyl residues may be made, with particular interest in introducing spectral labels into tyrosyl residues by reaction with aromatic diazonium compounds or tetranitromethane. Most commonly, N-acetylimidazole and tetranitromethane are used to form O-acetyl tyrosyl species and 3-nitro derivatives, respectively. Tyrosyl residues are iodinated using  $^{125}I$  or  $^{131}I$  to prepare labeled proteins for use in radioimmunoassay, the chloramine T method described above being suitable.

Carboxyl side groups (aspartyl or glutamyl) are selectively modified by reaction with carbodiimides ( $R'-N=C=N-R'$ ), where R and R' are different alkyl groups, such as 1-cyclohexyl-3-(2-morpholinyl-4-ethyl) carbodiimide or 1-ethyl-3-(4-azonia-4,4-dimethylpentyl) carbodiimide. Furthermore, aspartyl and glutamyl residues are converted to asparaginy and glutaminy residues by reaction with ammonium ions.

Derivatization with bifunctional agents is useful for crosslinking HRG to a water-insoluble support matrix or surface for use in the method for purifying anti-HRG antibodies, and vice versa. Commonly used crosslinking agents include, e.g., 1,1-bis(diazoacetyl)-2-phenylethane, glutaraldehyde, N-hydroxysuccinimide esters, for example, esters with 4-azidosalicylic acid, homobifunctional imidoesters, including disuccinimidyl esters such as 3,3'-dithiobis(succinimidylpropionate), and bifunctional maleimides such as bis-N-maleimido-1,8-octane. Derivatizing agents such as methyl-3-[(p-azidophenyl)dithio]propioimide yield photoactivatable intermediates that are capable of forming crosslinks in the presence of light. Alternatively, reactive water-insoluble matrices such as cyanogen bromide-activated carbohydrates and the reactive substrates described in U.S. Pat. Nos. 3,969,287; 3,691,016; 4,195,128; 4,247,642; 4,229,537; and 4,330,440 are employed for protein immobilization.

Glutaminy and asparaginy residues are frequently deamidated to the corresponding glutamyl and aspartyl residues, respectively. Alternatively, these residues are deamidated under mildly acidic conditions. Either form of these residues falls within the scope of this invention.

Other modifications include hydroxylation of proline and lysine, phosphorylation of hydroxyl groups of seryl or threonyl residues, methylation of the  $\alpha$ -amino groups of lysine, arginine, and histidine side chains (T.E. Creighton, Proteins: Structure and Molecular Properties, W.H. Freeman & Co., San Francisco, pp. 79-86 [1983]), acetylation of the N-terminal amine, and amidation of any C-terminal carboxyl group.

HRG optionally is fused with a polypeptide heterologous to HRG. The heterologous polypeptide optionally is an anchor sequence such as that found in the decay accelerating system (DAF); a toxin such as ricin, pseudomonas exotoxin, gelonin, or other polypeptide that will result in target cell death. These heterologous polypeptides are covalently coupled to HRG through side chains or through the terminal residues. Similarly, HRG is conjugated to other molecules toxic or inhibitory to a target mammalian cell, e.g. such as tricothecenes, or antisense DNA that blocks expression of target genes.

HRG also is covalently modified by altering its native glycosylation pattern. One or more carbohydrate substituents are modified by adding, removing or varying the monosaccharide components at a given site, or by modifying residues in HRG such that glycosylation sites are added or deleted.

Glycosylation of polypeptides is typically either N-linked or O-linked. N-linked refers to the attachment of the carbohydrate moiety to the side chain of an asparagine residue. The tri-peptide sequences asparagine-X-serine and asparagine-X-threonine, where X is any

amino acid except proline, are the recognition sequences for enzymatic attachment of the carbohydrate moiety to the asparagine side chain. Thus, the presence of either of these tri-peptide sequences in a polypeptide creates a potential glycosylation site. O-linked glycosylation refers to the attachment of one of the sugars N-acetylgalactosamine, galactose, or xylose, to a hydroxyamino acid, most commonly serine or threonine, although 5-hydroxyproline or 5-hydroxylysine may also be used.

Glycosylation sites are added to HRG by altering its amino acid sequence to contain one or more of the above-described tri-peptide sequences (for N-linked glycosylation sites). The alteration may also be made by the addition of, or substitution by, one or more serine or threonine residues to HRG (for O-linked glycosylation sites). For ease, HRG is preferably altered through changes at the DNA level, particularly by mutating the DNA encoding HRG at preselected bases such that codons are generated that will translate into the desired amino acids.

Chemical or enzymatic coupling of glycosides to HRG increases the number of carbohydrate substituents. These procedures are advantageous in that they do not require production of the polypeptide in a host cell that is capable of N- and O- linked glycosylation. Depending on the coupling mode used, the sugar(s) may be attached to (a) arginine and histidine, (b) free carboxyl groups, (c) free sulfhydryl groups such as those of cysteine, (d) free hydroxyl groups such as those of serine, threonine, or hydroxyproline, (e) aromatic residues such as those of phenylalanine, tyrosine, or tryptophan, or (f) the amide group of glutamine. These methods are described in WO 87/05330, published 11 September 1987, and in Aplin and Wriston (*CRC Crit. Rev. Biochem.*, pp. 259-306 [1981]).

Carbohydrate moieties present on an HRG also are removed chemically or enzymatically. Chemical deglycosylation requires exposure of the polypeptide to the compound trifluoromethanesulfonic acid, or an equivalent compound. This treatment results in the cleavage of most or all sugars except the linking sugar (N-acetylglucosamine or N-acetylgalactosamine), while leaving the polypeptide intact. Chemical deglycosylation is described by Hakimuddin *et al.* (*Arch. Biochem. Biophys.*, 259:52 [1987]) and by Edge *et al.* (*Anal. Biochem.*, 118:131 [1981]). Carbohydrate moieties are removed from HRG by a variety of endo- and exo- glycosidases as described by Thotakura *et al.* (*Meth. Enzymol.*, 138:350 [1987]).

Glycosylation added during expression in cells also is suppressed by tunicamycin as described by Duskin *et al.* (*J. Biol. Chem.*, 257:3105 [1982]). Tunicamycin blocks the formation of protein-N-glycoside linkages.

HRG also is modified by linking HRG to various nonproteinaceous polymers, e.g., polyethylene glycol, polypropylene glycol or polyoxyalkylenes, in the manner set forth in U.S. Pat. Nos. 4,640,835; 4,496,689; 4,301,144; 4,670,417; 4,791,192 or 4,179,337.

One preferred way to increase the *in vivo* circulating half life of non-membrane bound HRG is to conjugate it to a polymer that confers extended half-life, such as polyethylene

glycol (PEG). (Maxfield, *et al*, Polymer 16,505-509 [1975]; Bailey, F. E., *et al*, in Nonionic Surfactants [Schick, M. J., ed.] pp.794-821 [1967]; Abuchowski, A. *et al.*, J. Biol. Chem. 252:3582-3586 [1977]; Abuchowski, A. *et al.*, *Cancer Biochem. Biophys.* 7:175-186 [1984]; Katre, N.V. *et al.*, *Proc. Natl. Acad. Sci.*, 84:1487-1491 [1987]; Goodson, R. *et al.* *Bio Technology*, 8:343-346:[1990]). Conjugation to PEG also has been reported to have reduced immunogenicity and toxicity (Abuchowski, A. *et al.*, *J. Biol. Chem.*, 252:3578-3581 [1977]).

HRG also is entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization (for example, hydroxymethylcellulose or gelatin-microcapsules and poly-[methylmethacrylate] microcapsules, respectively), in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nanoparticles and nanocapsules), or in macroemulsions. Such techniques are disclosed in Remington's Pharmaceutical Sciences, 16th edition, Osol, A., Ed., (1980).

HRG is also useful in generating antibodies, as standards in assays for HRG (e.g., by labeling HRG for use as a standard in a radioimmunoassay, enzyme-linked immunoassay, or radioreceptor assay), in affinity purification techniques, and in competitive-type receptor binding assays when labeled with radioiodine, enzymes, fluorophores, spin labels, and the like.

Those skilled in the art will be capable of screening variants in order to select the optimal variant for the purpose intended. For example, a change in the immunological character of HRG, such as a change in affinity for a given antigen or for the HER2 receptor, is measured by a competitive-type immunoassay using a standard or control such as a native HRG (in particular native HRG-GFD). Other potential modifications of protein or polypeptide properties such as redox or thermal stability, hydrophobicity, susceptibility to proteolytic degradation, stability in recombinant cell culture or in plasma, or the tendency to aggregate with carriers or into multimers are assayed by methods well known in the art.

#### 1. Therapeutic use of Heregulin Ligands

While the role of the p185<sup>HER2</sup> and its ligands is unknown in normal cell growth and differentiation, it is an object of the present invention to develop therapeutic uses for the p185<sup>HER2</sup> ligands of the present invention in promoting normal growth and development and in inhibiting abnormal growth, specifically in malignant or neoplastic tissues.

#### 2. Therapeutic Compositions and Administration of HRG

Therapeutic formulations of HRG or HRG antibody are prepared for storage by mixing the HRG protein having the desired degree of purity with optional physiologically acceptable carriers, excipients, or stabilizers (Remington's Pharmaceutical Sciences, *supra*), in the form of lyophilized cake or aqueous solutions. Acceptable carriers, excipients or stabilizers are nontoxic to recipients at the dosages and concentrations employed, and include buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid; low molecular weight (less than about 10 residues) polypeptides (to prevent methoxide formation); proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, arginine or

lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrans; chelating agents such as EDTA; sugar alcohols such as mannitol or sorbitol; salt-forming counterions such as sodium; and/or nonionic surfactants such as Tween, Pluronics or polyethylene glycol (PEG).

5 HRG or HRG antibody to be used for *in vivo* administration must be sterile. This is readily accomplished by filtration through sterile filtration membranes, prior to or following lyophilization and reconstitution. HRG or antibody to an HRG ordinarily will be stored in lyophilized form or in solution.

Therapeutic HRG, or HRG specific antibody compositions generally are placed into a  
10 container having a sterile access port, for example, an intravenous solution bag or vial having a stopper pierceable by a hypodermic injection needle.

HRG, its antibody or HRG variant when used as an antagonist may be optionally combined with or administered in concert with other agents known for use in the treatment of malignancies. When HRG is used as an agonist to stimulate the HER2 receptor, for example in  
15 tissue cultures, it may be combined with or administered in concert with other compositions that stimulate growth such as PDGF, FGF, EGF, growth hormone or other protein growth factors.

The route of HRG or HRG antibody administration is in accord with known methods, e.g., injection or infusion by intravenous, intraperitoneal, intracerebral, intramuscular,  
20 intraocular, intraarterial, or intralesional routes, or by sustained release systems as noted below. HRG is administered continuously by infusion or by bolus injection. HRG antibody is administered in the same fashion, or by administration into the blood stream or lymph.

Suitable examples of sustained-release preparations include semipermeable matrices of solid hydrophobic polymers containing the protein, which matrices are in the form of shaped  
25 articles, e.g. films, or microcapsules. Examples of sustained-release matrices include polyesters, hydrogels [e.g., poly(2-hydroxyethyl-methacrylate) as described by Langer *et al.*, *J. Biomed. Mater. Res.*, 15:167-277 (1981) and Langer, *Chem. Tech.*, 12:98-105 (1982) or poly(vinylalcohol)], polylactides (U.S. Pat. No. 3,773,919, EP 58,481), copolymers of L-glutamic acid and gamma ethyl-L-glutamate (Sidman *et al.*, *Biopolymers*, 22:547-556 [1983]),  
30 non-degradable ethylene-vinyl acetate (Langer *et al.*, *supra*), degradable lactic acid-glycolic acid copolymers such as the Lupron Depot<sup>TM</sup> (injectable microspheres composed of lactic acid-glycolic acid copolymer and leuprolide acetate), and poly-D-(-)-3-hydroxybutyric acid (EP 133,988). While polymers such as ethylene-vinyl acetate and lactic acid-glycolic acid enable release of molecules for over 100 days, certain hydrogels release proteins for shorter time  
35 periods. When encapsulated proteins remain in the body for a long time, they may denature or aggregate as a result of exposure to moisture at 37°C, resulting in a loss of biological activity and possible changes in immunogenicity. Rational strategies can be devised for protein stabilization depending on the mechanism involved. For example, if the aggregation mechanism is discovered to be intermolecular S-S bond formation through thio-disulfide interchange.



stabilization may be achieved by modifying sulfhydryl residues, lyophilizing from acidic solutions, controlling moisture content, using appropriate additives, and developing specific polymer matrix compositions.

Sustained-release HRG or antibody compositions also include liposomally entrapped  
5 HRG or antibody. Liposomes containing HRG or antibody are prepared by methods known *per se*: DE 3,218,121; Epstein *et al.*, *Proc. Natl. Acad. Sci. USA*, 82:3688-3692 (1985); Hwang *et al.*, *Proc. Natl. Acad. Sci. USA*, 77:4030-4034 (1980); EP 52,322; EP 36,676; EP 88,046; EP 143,949; EP 142,641; Japanese patent application 83-118008; U.S. Pat. No. 4,485,045 and 4,544,545; and EP 102,324. Ordinarily the liposomes are of the small (about 200-800  
10 Angstroms) unilamellar type in which the lipid content is greater than about 30 mol. % cholesterol, the selected proportion being adjusted for the optimal HRG therapy. Liposomes with enhanced circulation time are disclosed in U.S. Pat. No. 5,013,556.

Another use of the present invention comprises incorporating HRG polypeptide or antibody into formed articles. Such articles can be used in modulating cellular growth and  
15 development. In addition, cell growth and division and tumor invasion may be modulated with these articles.

An effective amount of HRG or antibody to be employed therapeutically will depend, for example, upon the therapeutic objectives, the route of administration, and the condition of the patient. Accordingly, it will be necessary for the therapist to titer the dosage and modify  
20 the route of administration as required to obtain the optimal therapeutic effect. A typical daily dosage might range from about 1 µg/kg to up to 100 mg/kg or more, depending on the factors mentioned above. Typically, the clinician will administer HRG or antibody until a dosage is reached that achieves the desired effect. The progress of this therapy is easily monitored by conventional assays.

### 25 3. Heregulin Antibody Preparation and Therapeutic Use

The antibodies of this invention are obtained by routine screening. Polyclonal antibodies to HRG generally are raised in animals by multiple subcutaneous (sc) or intraperitoneal (ip) injections of HRG and an adjuvant. It may be useful to conjugate HRG or an HRG fragment containing the target amino acid sequence to a protein that is immunogenic  
30 in the species to be immunized, e.g., keyhole limpet hemocyanin, serum albumin, bovine thyroglobulin, or soybean trypsin inhibitor using a bifunctional or derivatizing agent, for example, maleimidobenzoyl sulfosuccinimide ester (conjugation through cysteine residues), N-hydroxysuccinimide (through lysine residues), glutaraldehyde, succinic anhydride, SOCl<sub>2</sub>, or R<sup>1</sup>N = C = NR, where R and R<sup>1</sup> are different alkyl groups.

The route and schedule of immunizing an animal or removing and culturing antibody-producing cells are generally in keeping with established and conventional techniques for antibody stimulation and production. While mice are frequently immunized, it is contemplated that any mammalian subject including human subjects or antibody-producing cells obtained  
35 therefrom can be immunized to generate antibody producing cells.

Subjects are typically immunized against HRG or its immunogenic conjugates or derivatives by combining 1 mg or 1  $\mu$ g of HRG immunogen (for rabbits or mice, respectively) with 3 volumes of Freund's complete adjuvant and injecting the solution intradermally at multiple sites. One month later the subjects are boosted with 1/5 to 1/10 the original amount of immunogen in Freund's complete adjuvant (or other suitable adjuvant) by subcutaneous injection at multiple sites. 7 to 14 days later animals are bled and the serum is assayed for anti-HRG antibody titer. Subjects are boosted until the titer plateaus. Preferably, the subject is boosted with a conjugate of the same HRG, but conjugated to a different protein and/or through a different cross-linking agent. Conjugates also can be made in recombinant cell culture as protein fusions. Also, aggregating agents such as alum are used to enhance the immune response.

After immunization, monoclonal antibodies are prepared by recovering immune lymphoid cells--typically spleen cells or lymphocytes from lymph node tissue--from immunized animals and immortalizing the cells in conventional fashion, e.g., by fusion with myeloma cells or by Epstein-Barr (EB)-virus transformation and screening for clones expressing the desired antibody. The hybridoma technique described originally by Kohler and Milstein, *Eur. J. Immunol.* 6:511 (1976) has been widely applied to produce hybrid cell lines that secrete high levels of monoclonal antibodies against many specific antigens.

It is possible to fuse cells of one species with another. However, it is preferable that the source of the immunized antibody producing cells and the myeloma be from the same species.

Hybridoma cell lines producing antiHRG are identified by screening the culture supernatants for antibody which binds to HRG. This is routinely accomplished by conventional immunoassays using soluble HRG preparations or by FACS using cell-bound HRG and labelled candidate antibody.

The hybrid cell lines can be maintained in culture *in vitro* in cell culture media. The cell lines of this invention can be selected and/or maintained in a composition comprising the continuous cell line in hypoxanthine-aminopterin thymidine (HAT) medium. In fact, once the hybridoma cell line is established, it can be maintained on a variety of nutritionally adequate media. Moreover, the hybrid cell lines can be stored and preserved in any number of conventional ways, including freezing and storage under liquid nitrogen. Frozen cell lines can be revived and cultured indefinitely with resumed synthesis and secretion of monoclonal antibody. The secreted antibody is recovered from tissue culture supernatant by conventional methods such as precipitation, ion exchange chromatography, affinity chromatography, or the like. The antibodies described herein are also recovered from hybridoma cell cultures by conventional methods for purification of IgG or IgM as the case may be that heretofore have been used to purify these immunoglobulins from pooled plasma, e.g., ethanol or polyethylene glycol precipitation procedures. The purified antibodies are sterile filtered, and optionally are

conjugated to a detectable marker such as an enzyme or spin label for use in diagnostic assays of HRG in test samples.

While mouse monoclonal antibodies routinely are used, the invention is not so limited; in fact, human antibodies may be used and may prove to be preferable. Such antibodies can be  
5 obtained by using human hybridomas (Cote *et al.*, *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, p. 77 (1985)). Chimeric antibodies, Cabilly *et al.*, (Morrison *et al.*, *Proc. Natl. Acad. Sci.*, 81:6851 (1984); Neuberger *et al.*, *Nature* 312:604 (1984); Takeda *et al.*, *Nature* 314:452 (1985)) containing a murine anti-HRG variable region and a human constant  
10 region of appropriate biological activity (such as ability to activate human complement and mediate ADCC) are within the scope of this invention, as are humanized anti-HRG antibodies produced by conventional CRD-grafting methods.

Techniques for creating recombinant DNA versions of the antigen-binding regions of antibody molecules (known as Fab or variable regions fragments) which bypass the generation of monoclonal antibodies are encompassed within the practice of  
15 this invention. One extracts antibody-specific messenger RNA molecules from immune system cells taken from an immunized subject, transcribes these into complementary DNA (cDNA), and clones the cDNA into a bacterial expression system and selects for the desired binding characteristic. The Scripps/Stratagene method uses a bacteriophage lambda vector system containing a leader sequence that causes the expressed Fab protein to migrate to the  
20 periplasmic space (between the bacterial cell membrane and the cell wall) or to be secreted. One can rapidly generate and screen great numbers of functional Fab fragments to identify those which bind HRG with the desired characteristics.

Antibodies specific to HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2 and HRG- $\beta$ 3 may be produced and used in the manner described above. HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2 and HRG- $\beta$ 3 specific  
25 antibodies of this invention preferably do not cross-react with other members of the EGF family (Fig. 6) or with each other.

Antibodies capable of specifically binding to the HRG-NTD, HRG-GFD or HRG-CTP are of particular interest. Also of interest are antibodies capable of specifically binding to the proteolytic processing sites between the GFD and transmembrane domains. These antibodies  
30 are identified by methods that are conventional per se. For example, a bank of candidate antibodies capable of binding to HRG-ECD or proHRG are obtained by the above methods using immunization with full proHRG. These can then be subdivided by their ability to bind to the various HRG domains using conventional mapping techniques. Less preferably, antibodies specific for a predetermined domain are initially raised by immunizing the subject with a  
35 polypeptide comprising substantially only the domain in question, e.g. HRG-GFD free of NTD or CTP polypeptides. These antibodies will not require mapping unless binding to a particular epitope is desired.

Antibodies that are capable of binding to proteolytic processing sites are of particular interest. They are produced either by immunizing with an HRG fragment that includes the

CTP processing site, with intact HRG, or with HRG-NTD-GFD and then screening for the ability to block or inhibit proteolytic processing of HRG into the NTD-GFD fragment by recombinant host cells or isolated cell lines that are otherwise capable of processing HRG to the fragment. These antibodies are useful for suppressing the release of NTD-GFD and therefore are promising for use in preventing the release of NTD-GFD and stimulation of the HER-2 receptor. They also are useful in controlling cell growth and replication. Anti-GFD antibodies are useful for the same reasons, but may not be as efficient biologically as antibodies directed against a processing site.

Antibodies are selected that are capable of binding only to one of the members of the HRG family, e.g. HRG-alpha or any one of the HRG-beta isoforms. Since each of the HRG family members has a distinct GFD-transmembrane domain cleavage site, antibodies directed specifically against these unique sequences will enable the highly specific inhibition of each of the GFDs or processing sites, and thereby refine the desired biological response. For example, breast carcinoma cells which are HER-2 dependent may in fact be activated only by a single GFD isotype or, if not, the activating GFD may originate only from a particular processing sequence, either on the HER-2 bearing cell itself or on a GFD-generating cell. The identification of the target activating GFD or processing site is a straight-forward matter of analyzing HER-2 dependent carcinomas, e.g., by analyzing the tissues for the presence of a particular GFD family member associated with the receptor, or by analyzing the tissues for expression of an HRG family member (which then would serve as the therapeutic target). These selective antibodies are produced in the same fashion as described above, either by immunization with the target sequence or domain, or by selecting from a bank of antibodies having broader specificity.

As described above, the antibodies should have high specificity and affinity for the target sequence. For example, the antibodies directed against GFD sequences should have greater affinity for the GFD than GFD has for the HER-2 receptor. Such antibodies are selected by routine screening methods.

#### 4. Non-Therapeutic Uses of Heregulin and its Antibodies

The nucleic acid encoding HRG may be used as a diagnostic for tissue specific typing. For example, such procedures as *in situ* hybridization, and Northern and Southern blotting, and PCR analysis may be used to determine whether DNA and/or RNA encoding HRG are present in the cell type(s) being evaluated. In particular, the nucleic acid may be useful as a specific probe for certain types of tumor cells such as, for example, mammary gland, gastric and colon adenocarcinomas, salivary gland and other tissues containing the p185<sup>HER2</sup>.

Isolated HRG may be used in quantitative diagnostic assays as a standard or control against which samples containing unknown quantities of HRG may be compared.

Isolated HRG may be used as a growth factor for *invitro* cell culture, and *invivo* to promote the growth of cells containing p185<sup>HER2</sup> or other analogous receptors.

HRG antibodies are useful in diagnostic assays for HRG expression in specific cells or tissues. The antibodies are labeled in the same fashion as HRG described above and/or are immobilized on an insoluble matrix.

HRG antibodies also are useful for the affinity purification of HRG from recombinant  
5 cell culture or natural sources. HRG antibodies that do not detectably cross-react with other HRG can be used to purify HRG free from other known ligands or contaminating protein.

Suitable diagnostic assays for HRG and its antibodies are well known *per se*. Such assays include competitive and sandwich assays, and steric inhibition assays. Competitive and sandwich methods employ a phase-separation step as an integral part of the method  
10 while steric inhibition assays are conducted in a single reaction mixture. Fundamentally, the same procedures are used for the assay of HRG and for substances that bind HRG, although certain methods will be favored depending upon the molecular weight of the substance being assayed. Therefore, the substance to be tested is referred to herein as an analyte, irrespective of its status otherwise as an antigen or antibody, and proteins that bind to the  
15 analyte are denominated binding partners, whether they be antibodies, cell surface receptors, or antigens.

Analytical methods for HRG or its antibodies all use one or more of the following reagents: labeled analyte analogue, immobilized analyte analogue, labeled binding partner, immobilized binding partner and steric conjugates. The labeled reagents also are known as  
20 "tracers."

The label used (and this is also useful to label HRG encoding nucleic acid for use as a probe) is any detectable functionality that does not interfere with the binding of analyte and its binding partner. Numerous labels are known for use in immunoassay, examples including moieties that may be detected directly, such as fluorochrome, chemiluminescent, and  
25 radioactive labels, as well as moieties, such as enzymes, that must be reacted or derivatized to be detected. Examples of such labels include the radioisotopes  $^{32}\text{P}$ ,  $^{14}\text{C}$ ,  $^{125}\text{I}$ ,  $^3\text{H}$ , and  $^{131}\text{I}$ , fluorophores such as rare earth chelates or fluorescein and its derivatives, rhodamine and its derivatives, dansyl, umbelliferone, luciferases, e.g., firefly luciferase and bacterial luciferase (U.S. Pat. No. 4,737,456), luciferin, 2,3-dihydrophthalazinediones, horseradish  
30 peroxidase (HRP), alkaline phosphatase,  $\beta$ -galactosidase, glucoamylase, lysozyme, saccharide oxidases, e.g., glucose oxidase, galactose oxidase, and glucose-6-phosphate dehydrogenase, heterocyclic oxidases such as uricase and xanthine oxidase, coupled with an enzyme that employs hydrogen peroxide to oxidize a dye precursor such as HRP, lactoperoxidase, or microperoxidase, biotin/avidin, spin labels, bacteriophage labels, stable  
35 free radicals, and the like.

Conventional methods are available to bind these labels covalently to proteins or polypeptides. For instance, coupling agents such as dialdehydes, carbodiimides, dimaleimides, bis-imidates, bis-diazotized benzidine, and the like may be used to tag the antibodies with the above-described fluorescent, chemiluminescent, and enzyme labels. See, for example, U.S.

Pat. Nos. 3,940,475 (fluorimetry) and 3,645,090 (enzymes); Hunter *et al.*, *Nature*, 144:945 (1962); David *et al.*, *Biochemistry*, 13:1014-1021 (1974); Pain *et al.*, *J. Immunol. Methods*, 40:219-230 (1981); and Nygren, *J. Histochem. and Cytochem.*, 30:407-412 (1982). Preferred labels herein are enzymes such as horseradish peroxidase and alkaline phosphatase. The conjugation of such label, including the enzymes, to the antibody is a standard manipulative procedure for one of ordinary skill in immunoassay techniques. See, for example, O'Sullivan *et al.*, "Methods for the Preparation of Enzyme-antibody Conjugates for Use in Enzyme Immunoassay," in Methods in Enzymology, ed. J.J. Langone and H. Van Vunakis, Vol. 73 (Academic Press, New York, New York, 1981), pp. 147-166. Such bonding methods are suitable for use with HRG or its antibodies, all of which are proteinaceous.

Immobilization of reagents is required for certain assay methods. Immobilization entails separating the binding partner from any analyte that remains free in solution. This conventionally is accomplished by either insolubilizing the binding partner or analyte analogue before the assay procedure, as by adsorption to a water-insoluble matrix or surface (Bennich *et al.*, U.S. Pat. No. 3,720,760), by covalent coupling (for example, using glutaraldehyde cross-linking), or by insolubilizing the partner or analogue afterward, e.g., by immunoprecipitation.

Other assay methods, known as competitive or sandwich assays, are well established and widely used in the commercial diagnostics industry.

Competitive assays rely on the ability of a tracer analogue to compete with the test sample analyte for a limited number of binding sites on a common binding partner. The binding partner generally is insolubilized before or after the competition and then the tracer and analyte bound to the binding partner are separated from the unbound tracer and analyte. This separation is accomplished by decanting (where the binding partner was preinsolubilized) or by centrifuging (where the binding partner was precipitated after the competitive reaction). The amount of test sample analyte is inversely proportional to the amount of bound tracer as measured by the amount of marker substance. Dose-response curves with known amounts of analyte are prepared and compared with the test results to quantitatively determine the amount of analyte present in the test sample. These assays are called ELISA systems when enzymes are used as the detectable markers.

Another species of competitive assay, called a "homogeneous" assay, does not require a phase separation. Here, a conjugate of an enzyme with the analyte is prepared and used such that when anti-analyte binds to the analyte the presence of the anti-analyte modifies the enzyme activity. In this case, HRG or its immunologically active fragments are conjugated with a bifunctional organic bridge to an enzyme such as peroxidase. Conjugates are selected for use with anti-HRG so that binding of the anti-HRG antibody inhibits or potentiates the enzyme activity of the label. This method *per se* is widely practiced under the name of EMIT.

Steric conjugates are used in steric hindrance methods for homogeneous assay. These conjugates are synthesized by covalently linking a low-molecular-weight hapten to a

small analyte so that antibody to hapten substantially is unable to bind the conjugate at the same time as anti-analyte. Under this assay procedure the analyte present in the test sample will bind anti-analyte, thereby allowing anti-hapten to bind the conjugate, resulting in a change in the character of the conjugate hapten, e.g., a change in fluorescence when the  
5 hapten is a fluorophore.

Sandwich assays particularly are useful for the determination of HRG or HRG antibodies. In sequential sandwich assays an immobilized binding partner is used to adsorb test sample analyte, the test sample is removed as by washing, the bound analyte is used to adsorb labeled binding partner, and bound material is then separated from residual tracer.  
10 The amount of bound tracer is directly proportional to test sample analyte. In "simultaneous" sandwich assays the test sample is not separated before adding the labeled binding partner. A sequential sandwich assay using an anti-HRG monoclonal antibody as one antibody and a polyclonal anti-HRG antibody as the other is useful in testing samples for HRG activity.

The foregoing are merely exemplary diagnostic assays for HRG and antibodies.  
15 Other methods now or hereafter developed for the determination of these analytes are included within the scope hereof, including the bioassays described above.

HRG polypeptides may be used for affinity purification of receptors such as the p185<sup>HER2</sup> and other similar receptors that have a binding affinity for HRG, and more specifically HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2 and HRG- $\beta$ 3. HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2 and HRG-  
20  $\beta$ 3 may be used to form fusion polypeptides wherein HRG portion is useful for affinity binding to nucleic acids and to heparin.

HRG polypeptides may be used as ligands for competitive screening of potential agonists or antagonists for binding to p185<sup>HER2</sup>. HRG variants are useful as standards or controls in assays for HRG provided that they are recognized by the analytical system  
25 employed, e.g. an anti-HRG antibody. Antibody capable of binding to denatured HRG or a fragment thereof, is employed in assays in which HRG is denatured prior to assay, and in this assay the denatured HRG or fragment is used as a standard or control. Preferably, HRG- $\alpha$ , HRG- $\beta$ 1, HRG- $\beta$ 2 and HRG- $\beta$ 3 are detectably labelled and a competition assay for bound p185<sup>HER2</sup> is conducted using standard assay procedures.

30 The methods and procedures described herein with HRG- $\alpha$  may be applied similarly to HRG- $\beta$ 1, HRG- $\beta$ 2 and HRG- $\beta$ 3 and to other novel HRG ligands and to their variants. The following examples are offered by way of illustration and not by way of limitation.

## EXAMPLES

35

### Example 1

#### Preparation of Breast Cancer Cell Supernatants

Heregulin- $\alpha$  was isolated from the supernatant of the human breast carcinoma MDA-MB-231. HRG was released into and isolated from the cell culture medium.

a. Cell Culture

MDA-MB-231, human breast carcinoma cells, obtainable from the American Type Culture Collection (ATCC HTB 26), were initially scaled-up from 25 cm<sup>2</sup> tissue culture flasks to 890 cm<sup>2</sup> plastic roller bottles (Coming, Coming, N Y) by serial passaging and the seed train was maintained at the roller bottle scale. To passage the cells and maintain the seed train, flasks and roller bottles were first rinsed with phosphate buffered saline (PBS) and then incubated with trypsin/EDTA (Sigma, St. Louis, Mo) for 1-3 minutes at 37°C. The detached cells were then pipetted several times in fresh culture medium containing fetal bovine serum (FBS), (Gibco, Grand Island, NY) to break up cell clumps and to inactivate the trypsin. The cells were finally split at a ratio of 1:10 into fresh medium, transferred into new flasks or bottles, incubated at 37°C, and allowed to grow until nearly confluent. The growth medium in which the cells were maintained was a combined DME/Ham's-F-12 medium formulation modified with respect to the concentrations of some amino acids, vitamins, sugars, and salts, and supplemented with 5% FBS. The same basal medium is used for the serum-free ligand production and is supplemented with 0.5% Primatone RL (Sheffield, Norwich, NY).

b. Large Scale Production

Large scale MDA-MB-231 cell growth was obtained by using Percoll Biolytica microcarriers (Hyclone Laboratories, Logan, UT) made of weighted cross-linked gelatin. The microcarriers were first hydrated, autoclaved, and rinsed according to the manufacturer's recommendations. Cells from 10 roller bottles were trypsinized and added into an inoculation spinner vessel which contained three liters of growth medium and 10-20 g of hydrated microcarriers. The cells were stirred gently for about one hour and transferred into a ten-liter instrumented fermenter containing seven liters of growth medium. The culture was agitated at 65-75 rpm to maintain the microcarriers in suspension. The fermenter was controlled at 37°C and the pH was maintained at 7.0-7.2 by the addition of sodium carbonate and CO<sub>2</sub>. Air and oxygen gases were sparged to maintain the culture at about 40% of air saturation. The cell population was monitored microscopically with a fluorescent vital stain (fluorescein diacetate) and compared to trypan blue staining to assess the relative cell viability and the degree of microcarrier invasion by the cells. Changes in cell-microcarrier aggregate size were monitored by microscopic photography.

Once the microcarriers appeared 90-100% confluent, the culture was washed with serum-free medium to remove the serum. This was accomplished by stopping the agitation and other controls to allow the carriers to settle to the bottom of the vessel. Approximately nine liters of the culture supernatant were pumped out of the vessel and replaced with an equal volume of serum-free medium (the same basal medium described as above supplemented either with or without Primatone RL). The microcarriers were briefly resuspended and the process was repeated until a 1000 fold removal of FBS was achieved. The cells were then incubated in the serum-free medium for 3-5 days. The glucose concentration in the culture was monitored daily and supplemented with additions of glucose as needed to maintain the



concentration in the fermenter at or above 1 g/L. At the time of harvest, the microcarriers were settled as described above and the supernatant was aseptically removed and stored at 2-8°C for purification. Fresh serum-free medium was replaced into the fermenter, the microcarriers were resuspended, and the culture was incubated and harvested as before.

5 This procedure could be repeated four times.

## Example 2

### Purification of Growth Factor Activity

Conditioned media (10-20 liters) from MDA-MB-231 cells was clarified by  
10 centrifugation at 10,000 rpm in a Sorvall Centrifuge, filtered through a 0.22 micron filter and  
then concentrated 10-50 (approx. 25) fold with a Minitan Tangential Flow Unit (Millipore  
Corp.) with a 10 kDa cutoff polysulfone membrane at room temperature. Alternatively,  
media was concentrated with a 2.5L Amicon Stirred Cell at 4°C with a YM3 membrane.  
After concentration, the media was again centrifuged at 10,000 rpm and the supernatant  
15 frozen in 35-50 ml aliquots at -80°C.

Heparin Sepharose was purchased from Pharmacia (Piscataway, NJ) and was  
prepared according to the directions of the manufacturer. Five milliliters of the resin was  
packed into a column and was extensively washed (100 column volumes) and equilibrated with  
phosphate buffered saline (PBS). The concentrated conditioned media was thawed, filtered  
20 through a 0.22 micron filter to remove particulate material and loaded onto the heparin-  
Sepharose column at a flow rate of 1 ml / min. The normal load consisted of 30-50 mls of 40-  
fold concentrated media. After loading, the column was washed with PBS until the  
absorbance at 280 nm returned to baseline before elution of protein was begun. The column  
was eluted at 1 ml/min with successive salt steps of 0.3 M, 0.6 M, 0.9 M and (optionally) 2.0 M  
25 NaCl prepared in PBS. Each step was continued until the absorbance returned to baseline,  
usually 6-10 column volumes. Fractions of 1 milliliter volume were collected. All of the  
fractions corresponding to each wash or salt step were pooled and stored for subsequent  
assay in the MDA-MB-453 cell assay.

The majority of the tyrosine phosphorylation stimulatory activity was found in the  
30 0.6M NaCl pool which was used for the next step of purification. Active fractions from the  
heparin-Sepharose chromatography were thawed, diluted three fold with deionized (MilliQ)  
water to reduce the salt concentration and loaded onto a polyaspartic acid column (PolyCAT  
A, 4.6 x 100 mm, PolyLC, Columbia, MD.) equilibrated in 17 mM Na phosphate, pH 6.8. All  
buffers for this purification step contained 30% ethanol to improve the resolution of protein on  
35 this column. After loading, the column was washed with equilibration buffer and was eluted  
with a linear salt gradient from 0.3 M to 0.6 M NaCl in 17 mM Na phosphate, pH 6.8, buffer.  
The column was loaded and developed at 1 ml/min and 1 ml fractions were collected during the  
gradient elution. Fractions were stored at 4°C. Multiple heparin-Sepharose and PolyCat  
columns were processed in order to obtain sufficient material for the next purification step. A

typical absorbance profile from a PolyCat A column is shown in Figure 1. Aliquots of 10-25  $\mu$ L were taken from each fraction for assay and SDS gel analysis.

5 Tyrosine phosphorylation stimulatory activity was found throughout the eluted fractions of the PolyCAT A column with a majority of the activity found in the fractions corresponding to peak C of the chromatogram (salt concentration of approximately 0.45M NaCl). These fractions were pooled and adjusted to 0.1% trifluoroacetic acid (TFA) by addition of 0.1 volume of 1% TFA. Two volumes of deionized water were added to dilute the ethanol and salt from the previous step and the sample was subjected to further purification on high pressure liquid chromatography (HPLC) utilizing a C4 reversed phase column  
10 (SynChropak RP-4, 4.6 x100 mm) equilibrated in a buffer consisting of 0.1% TFA in water with 15% acetonitrile. The HPLC procedure was carried out at room temperature with a flow rate of 1 ml/min. After loading of the sample, the column was re-equilibrated in 0.1% TFA/15% acetonitrile. A gradient of acetonitrile was established such that over a 10 minute period of time the acetonitrile concentration increased from 15 to 25% (1%/min).  
15 Subsequently, the column was developed with a gradient from 25 to 40% acetonitrile over 60 min time (0.25%/min). Fractions of 1 ml were collected, capped to prevent evaporation, and stored at 4°C. Aliquots of 10 to 50  $\mu$ L were taken, reduced to dryness under vacuum (SpeedVac), and reconstituted with assay buffer (PBS with 0.1% bovine serum albumin) for the tyrosine phosphorylation assay. Additionally, aliquots of 10 to 50  $\mu$ L were taken and dried  
20 as above for analysis by SDS gel electrophoresis. A typical HPLC profile is shown in Figure 2

A major peak of activity was found in fraction 17 (Figure 2B). By SDS gel analysis, fraction 17 was found to contain a single major protein species which comigrated with the 45,000 dalton molecular weight standard (Figs. 2C, 3). In other preparations, the presence of  
25 the 45,000 dalton protein comigrated with the stimulation of tyrosine phosphorylation activity in the MDA-MB-453 cell assay. The chromatographic properties of the 45,000 dalton protein were atypical; in contrast to many other proteins in the preparation, the 45,000 dalton protein did not elute from the reversed phase column within 2 or 3 fractions. Instead, it was eluted over 5-10 fractions. This is possibly due to extensive post-translational modifications.

30 a. Protein Sequence Determination

Fractions containing the 45,000 dalton protein were dried under vacuum for amino acid sequencing. Samples were redissolved in 70% formic acid and loaded into an Applied Biosystems, Inc. Model 470A vapor phase sequencer for N-terminal sequencing. No discernable N-terminal sequence was obtained, suggesting that the N-terminal residue was  
35 blocked. Similar results were obtained when the protein was first run on an SDS gel, transblotted to ProBlott membrane and the 45,000 dalton band excised after localization by rapid staining with Coomassie Brilliant Blue.

Internal amino acid sequence was obtained by subjecting fractions containing the 45,000 dalton protein to partial digestion using either cyanogen bromide, to cleave at

methionine residues, Lysine-C to cleave at the C-terminal side of lysine residues, or Asp-N to cleave at the N-terminal side of aspartic acid residues. Samples after digestion were sequenced directly or the peptides were first resolved by HPLC chromatography on a Synchrom C4 column (4000A, 2 x 100 mm) equilibrated in 0.1% TFA and eluted with a 1-propanol gradient in 0.1% TFA. Peaks from the chromatographic run were dried under vacuum before sequencing.

Upon sequencing of the peptide in the peak designated number 15 (lysine C-15), several amino acids were found on each cycle of the run. After careful analysis, it was clear that the fraction contained the same basic peptide with several different N-termini, giving rise to the multiple amino acids in each cycle. After deconvolution, the following sequence was determined (SEQ ID NO:3):

[A] A E K E K T F [C] V N G G E X F M V K D L X N P  
 1        5        10        15        20

(Residues in brackets were uncertain while an X represents a cycle in which it was not possible to identify the amino acid.)

The initial yield was 8.5 pmoles. This sequence comprising 24 amino acids did not correspond to any previously known protein. Residue 1 was later found from the cDNA sequence to be Cys and residue 9 was found to be correct. The unknown amino acids at positions 15 and 22 were found to be Cys and Cys, respectively.

Sequencing on samples after cyanogen bromide and Asp-N digestions, but without separation by HPLC, were performed to corroborate the cDNA sequence. The sequences obtained are given in Table I and confirm the sequence for the 45,000 protein deduced from the cDNA sequence. The N-terminal of the protein appears to be blocked with an unknown blocking group. On one occasion, direct sequencing of the 45,000 dalton band from a PVDF blot revealed this sequence with a very small initial yield (0.2 pmole)(SEQ ID NO:4):

X E X K E (G) (R) G K (G) K (G) K K K E X G X G (K)

(Residues which could not be determined are represented by "X", while tentative residues are in parentheses). This corresponds to a sequence starting at the serine at position 46 near the present N-terminal of HRG cDNA sequence; this suggests that the N terminus of the 45,000 protein is at or before this point in the sequence.

### Example 3

#### Cloning and Sequencing of Human Heregulin

The cDNA cloning of the p185<sup>HER2</sup> ligand was accomplished as follows. A portion of the lysine C-15 peptide amino acid sequence was decoded in order to design a probe for cDNA's encoding the 45kD HRG- $\alpha$  ligand. The following 39 residue long eight fold degenerate deoxyoligonucleotide corresponding to the amino acid sequence(SEQ ID NO:5) NH<sub>2</sub>-...AEKEKTFXVNGGE was chemically synthesized (SEQ ID NO:6):

3' GCTGAGAAGGAGAAGACCTTCTGT/CGTGAAT/CGGA/CGGCGAG 5'.

The unknown amino acid residue designated by X in the amino acid sequence was assigned as cysteine for design of the probe. This probe was radioactively phosphorylated and employed to screen by low stringency hybridization an oligo dT primed cDNA library constructed from human MDA-MB-231 cell mRNA in  $\lambda$ gt10 (Huyng *et al.*, 1984, In DNA Cloning, Vol 1: A Practical Approach (D. Glover, ed) pp.49-78. IRL Press, Oxford). Two positive clones designated  $\lambda$ gt10her16 and  $\lambda$ gt10her13 were identified. DNA sequence analysis revealed that these two clones were identical.

The 2010 basepair cDNA nucleotide sequence of  $\lambda$ gt10her16 (Fig. 4) contains a single long open reading frame of 669 amino acids beginning with alanine at nucleotide positions 3-5 and ending with glutamine at nucleotide positions 2007-2009. No stop codon was found in the translated sequence; however, later analysis of heregulin  $\beta$ -type clones indicates that methionine encoded at nucleotide positions 135-137 was the initiating methionine. Nucleotide sequence homology with the probe is found between and including bases 681-719. Homology between those amino acids encoded by the probe and those flanking the probe with the amino acid sequence determined for the lysine C-15 fragment verify that the isolated clone encodes at least the lysine C-15 fragment of the 45kD protein.

Hydropathy analysis shows the existence of a strongly hydrophobic amino acid region including residues 287-309 (Fig. 4) indicating that this protein contains a transmembrane or internal signal sequence domain and thus is anchored to the membrane of the cell.

The 669 amino acid sequence encoded by the 2010bp cDNA sequence contains potential sites for asparagine-linked glycosylation (Winzler, R. in Hormonal Proteins and Peptides, ( Li, C.H. ed ) pp 1-15 Academic Press, New York (1973)) at positions asparagine 164, 170, 208, 437 and 609. A potential O-glycosylation site (Marshall, R.D. (1974) Biochem. Soc. Symp. 40:17-26) is presented in the region including a cluster of serine and threonine residues at amino acid positions 209-218. Three sites of potential glycosaminoglycan addition (Goldstein, L.A., *et al.* (1989) Cell 56:1063-1072) are positioned at the serine-glycine dipeptides occurring at amino acids 42-43, 64-65 and 151-152. Glycosylation probably accounts for the discrepancy between the calculated NW of about 26KD for the NTD-GFD (extracellular) region of HRG and the observed NW of about 45 KD for purified HRG.

This amino acid sequence shares a number of features with the epidermal growth factor (EGF) family of transmembrane bound growth factors (Carpenter, G., and Cohen, S. (1979) Ann. Rev. Biochem. 48: 193-216; Massenque, J. (1990) J. Biol. Chem. 265: 21393-21396) including 1) the existence of a proform of each growth factor from which the mature form is proteolytically released (Gray, A., Dull, T.J., and Ullrich, A. (1983) Nature 303, 722-725; Bell, G.I. *et al.*, (1986) Nuc. Acid Res., 14: 8427-8446; Derynck, R. *et al.* (1984) Cell: 287-297); 2) the conservation of six cysteine residues characteristically positioned over a span of approximately 40 amino acids (the EGF-like structural motif) (Savage, R.C., *et al.* (1973) J. Biol. Chem. 248: 7669-7672); HRG- $\alpha$  cysteines 226, 234, 240, 254, 256 and 265 ); and, 3) the

existence of a transmembrane domain occurring proximally on the carboxy-terminal side of the EGF homologous region (Fig. 4 and 6).

Alignment of the amino acid sequences in the region of the EGF motif and flanking transmembrane domain of several human EGF related proteins (Fig. 6) shows that between  
5 the first and sixth cysteine of the EGF motif HRG is most similar (50%) to the heparin binding EGF-like growth factor (HB-EGF) (Higashiyama, S. *et al.* (1991) *Science* 251: 936-939). In this same region HRG is ~35% homologous to amphiregulin (AR) (Plowman, G.D. *et al.*, (1990) *Mol. Cell. Biol.* 10: 1969-1981), ~32% homologous to transforming growth factor  $\alpha$  (TGF  $\alpha$ ) (8), 27% homologous with EGF (Bell, G.I. *et al.*, (1986) *Nuc. Acid Res.*, 14: 8427-8446); and  
10 39% homologous to the schwannoma-derived growth factor (Kimura, H., *et al.*, *Nature*, 348:257-260, 1990). Disulfide linkages between cysteine residues in the EGF motif have been determined for EGF (Savage, R.C. *et al.* (1973) *J. Biol. Chem.* 248: 7669-7672). These disulfides define the secondary structure of this region and demarcate three loops. By numbering the cysteines beginning with 1 on the amino-terminal end, loop 1 is delineated by  
15 cysteines 1 and 3; loop 2 by cysteines 2 and 4; and loop 3 by cysteines 5 and 6. Although the exact disulfide configuration in the region for the other members of the family has not been determined, the strict conservation of the six cysteines, as well as several other residues i.e., glycine 238 and 262 and arginine at position 264, indicate that they too most likely have the same arrangement. HRG- $\alpha$  and EGF both have 13 amino acids in loop 1. HB-EGF,  
20 amphiregulin (AR) and TGF  $\alpha$  have 12 amino acids in loop 1. Each member has 10 residues in loop 2 except HRG- $\alpha$  which has 13. All five members have 8 residues in the third loop.

EGF, AR, HB-EGF and TGF- $\alpha$  are all newly synthesized as membrane anchored proteins by virtue of their transmembrane domains. The proproteins are subsequently processed to yield mature active molecules. In the case of TGF- $\alpha$  there is evidence that the  
25 membrane associated proforms of the molecules are also biologically active (Brachmann, R., *et al.* (1989) *Cell* 56: 691-700), a trait that may also be the case for HRG- $\alpha$ . EGF is synthesized as a 1168 amino acid transmembrane bound proEGF that is cleaved on the amino-terminal end between arginine 970 and asparagine 971 and at the carboxy-terminal end between arginine 1023 and histidine 1024 (Carpenter, G., and Cohen, S. (1979) *Ann. Rev. Biochem.* 48: 193-216) to yield the 53 amino acid mature EGF molecule containing the three  
30 loop, 3 disulfide bond signature structure. The 252 amino acid proAR is cleaved between aspartic acid 100 and serine 101 and between lysine 184 and serine 185 to yield an 84 amino acid form of mature AR and a 78 amino acid form is generated by NH<sub>2</sub>-terminal cleavage between glutamine 106 and valine 107 (Plowman, G.D. *et al.*, (1990) *Mol. Cell. Biol.* 10: 1969-1981). HB-EGF is processed from its 208 amino acid primary translation product to its  
35 proposed 84 amino acid form by cleavage between arginine 73 and valine 74 and a second site approximately 84 amino acids away in the carboxy-terminal direction (Higashiyama, S., *et al.*, and Klagsburn, M. (1991) *Science* 251: 936-939). The 160 amino acid proform of TGF  $\alpha$  is processed to a mature 50 amino acid protein by cleavages between alanine 39 and valine 40

on one side and downstream cleavage between alanine 89 and valine 90 (Derynck *et al.*, (1984) Cell: 38: 287-297). For each of the above described molecules COOH-terminal processing occurs in the area bounded by the sixth cysteine of the EGF motif and the beginning of the transmembrane domain.

5       The residues between the first and sixth cysteines of HRGs are most similar (45%) to heparin-binding EGF-like growth factor (HB-EGF). In this same region they are 35% identical to amphiregulin (AR), 32% identical to TGF- $\alpha$ , and 27% identical with EGF. Outside of the EGF motif there is little similarity between HRGs and other members of the EGF family. EGF, AR, HB-EGF and TGF- $\alpha$  are all derived from membrane anchored proproteins  
10       which are processed on both sides of the EGF structural unit, yielding 50-84 amino acid mature proteins (16-19). Like other EGF family members, the HRGs appear to be derived from a membrane-bound proform but require only a single cleavage, C-terminal to the cysteine cluster, to produce mature protein.

      HRG may exert its biological function by binding to its receptor and triggering the  
15       transduction of a growth modulating signal. This it may accomplish as a soluble molecule or perhaps as its membrane anchored form such as is sometimes the case with TGF  $\alpha$  (Brachmann, R., *et al.*, (1989) Cell 56: 691-700). Conversely, or in addition to stimulating signal transduction, HRG may be internalized by a target cell where it may then interact with the controlling regions of other regulatory genes and thus directly deliver its message to the  
20       nucleus of the cell. The possibility that HRG mediates some of its effects by a mechanism such as this is suggested by the fact that a potential nuclear location signal (Roberts, Biochem-Biophys Acta (1989) 1008: 263-280) exists in the region around the three lysine residues at positions 58-60 (Fig. 4).

      The isolation of full-length cDNA of HRG- $\alpha$  is accomplished by employing the DNA  
25       sequence of Fig 4 to select additional cDNA sequences from the cDNA library constructed from human MDA-MB-231. Full-length cDNA clones encoding HRG- $\alpha$  are obtained by identifying cDNAs encoding HRG- $\alpha$  longer in both the 3' and 5' directions and then splicing together a composite of the different cDNAs. Additional cDNA libraries are constructed as required for this purpose. Following are three types of cDNA libraries that may be  
30       constructed: 1) Oligo-dT primed where predominately stretches of polyadenosine residues are primed, 2) random primed using short synthetic deoxyoligonucleotides non-specific for any particular region of the mRNA, and 3) specifically primed using short synthetic deoxyoligonucleotides specific for a desired region of the mRNA. Methods for the isolation of such cDNA libraries were previously described.

35

#### Example 4

##### Detection of HRG- $\alpha$ mRNA Expression by Northern Analyses

Northern blot analysis of MDA-MB-231 and SK-BR-3 cell mRNA under high stringency conditions shows at least five hybridizing bands in MDA-MB-231 mRNA where a 6.4Kb band predominates: other weaker bands are at 9.4, 6.9, 2.8 and 1.8Kb (Fig. 5). No hybridizing band

is seen in SK-BR-3 mRNA (this cell line overexpresses p185<sup>HER2</sup>). The existence of these multiple messages in MDA-MB-231 cells indicates either alternative splicing of the gene, various processing of the genes' primary transcript or the existence of a transcript of another homologous message. One of these messages may encode a soluble non-transmembrane bound form of HRG- $\alpha$ . Such messages (Fig. 5) may be used to produce cDNA encoding soluble non-transmembrane bound forms of HRG- $\alpha$ .

#### Example 5

##### Cell Growth Stimulation by Heregulin- $\alpha$

Several different breast cancer cell lines expressing the EGF receptor or the p185<sup>HER2</sup> receptor were tested for their sensitivity to growth inhibition or stimulation by ligand preparations. The cell lines tested were: SK-BR-3 (ATCC HTB 30), a cell line which overexpresses p185<sup>HER2</sup>; MDA-MB-468 (ATCC HTB 132), a line which overexpresses the EGF receptor; and MCF-7 cells (ATCC HTB 22) which have a moderate level of p185<sup>HER2</sup> expression. These cells were maintained in culture and passaged according to established cell culture techniques. The cells were grown in a 1:1 mixture of DMEM and F-12 media with 10% fetal bovine serum. For the assay, the stock cultures were treated with trypsin to detach the cells from the culture dish, and dispensed at a level of about 20000 cells/well in a ninety-six well microtiter plate. During the course of the growth assay they were maintained in media with 1% fetal bovine serum. The test samples were sterilized by filtration through 0.22 micron filters and they were added to quadruplicate wells and the cells incubated for 3-5 days at 37°C. At the end of the growth period, the media was aspirated from each well and the cells treated with crystal violet (Lewis, G. *et al.*, *Cancer Research*, **347**:5382-5385 [1987]). The amount of crystal violet absorbance which is proportional to the number of cells in each well was measured on a Flow Plate Reader. Values from replicate wells for each test sample were averaged. Untreated wells on each dish served as controls. Results were expressed as percent of growth relative to the control cells.

The purified HRG- $\alpha$  ligand was tested for activity in the cell growth assay and the results are presented in Figure 7. At a concentration of approximately 1 nM ligand, both of the cell lines expressing the p185<sup>HER2</sup> receptor (SK-BR-3 and MCF-7) showed stimulation of growth relative to the controls while the cell type (MDA-MB-468) expressing only the EGF receptor did not show an appreciable response. These results were consistent to those obtained from the autophosphorylation experiments with the various cell lines. These results established that HRG- $\alpha$  ligand is specific for the p185<sup>HER2</sup> receptor and does not show appreciable interaction with the EGF receptor at these concentrations.

HRG does not compete with antibodies directed against the extra-cellular domain of p185<sup>HER2</sup>, but anti-p185<sup>HER2</sup> Mabs 2C4 and 7F3 (which are antiproliferative in their own right) do antagonize HRG.

## Example 6

Cloning and Sequencing of Heregulin- $\beta$ 1

The isolation of HRG- $\beta$ 1 cDNA was accomplished by employing a hybridizing fragment of the DNA sequence encoding HRG- $\alpha$  to select additional cDNA sequences from the cDNA library constructed from human MDA-MB-231 cells. Clone  $\lambda$ her11.1db1 (heregulin- $\beta$ 1) was identified in a  $\lambda$ gt<sub>10</sub> oligo-dT primed cDNA library derived from MDA MB231 polyA<sup>+</sup> mRNA. Radioactively labelled synthetic DNA probes corresponding to the 5' and 3' ends of  $\lambda$ her16 (HRG- $\alpha$ ) were employed in a hybridization reaction under high stringency conditions to isolate the  $\lambda$ her11.1db1 clone. The DNA nucleotide sequence of the  $\lambda$ her11.1db1 clone is shown in figure 8 (SEQ ID NO:9). HRG- $\beta$ 1 amino acid sequence is homologous to HRG- $\alpha$  from its amino-terminal end at position Asp 15 of HRG- $\alpha$  through the 3'end of HRG- $\alpha$  except at the positions described below. In addition, HRG- $\beta$ 1 encoding DNA extends 189 base pairs longer than  $\lambda$ her16 in the 3' direction and supplies a stop codon after Val 675. At nucleotide position 247 of  $\lambda$ her11.1db1 there is a G substituted for A thereby resulting in the substitution of Gln(Q) in place of Arg(R) in HRG- $\beta$ 1 as shown in the second line of Figure 9 (SEQ ID NO:8 and SEQ ID NO:9).

In the area of the EGF motif there are additional differences between HRG- $\alpha$  and HRG- $\beta$ 1. These differences are illustrated below in an expanded view of the homology between HRG- $\alpha$  and HRG- $\beta$ 1 in the region of the EGF motif or the GFD (growth factor domain). The specific sequence shown corresponds to HRG- $\alpha$  amino acids 221-286 shown in figure 9. Asterisks indicate identical residues in the comparison below (SEQ ID NO:10 and SEQ ID NO:11).

HEREGULIN- $\alpha$	S	H	L	V	K	C	A	E	K	E	K	T	F	C	V	N	G	G	E	C	
HEREGULIN- $\beta$ 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
HEREGULIN- $\alpha$	F	M	V	K	D	L	S	N	P	S	R	Y	L	C	K	C	Q	P	G	F	
HEREGULIN- $\beta$ 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	P	N	E	*
HEREGULIN- $\alpha$	T	G	A	R	C	T	E	N	V	P	M	K	V	Q	N	Q	E	K	-	-	
HEREGULIN- $\beta$ 1	*	*	D	*	*	Q	N	Y	*	M	A	S	F	Y	K	H	L	G	I	E	
HEREGULIN- $\alpha$	-	-	-	A	E	E	L	Y	Q	K	R	(-Transmembrane)									
HEREGULIN- $\beta$ 1	F	M	E	*	*	*	*	*	*	*	*	(-Transmembrane)									

35

## Example 7

Expression of Heregulins in E. Coli

HRG- $\alpha$  and HRG- $\beta$ 1 have been expressed in E. coli using the DNA sequences of Figures 4 and 8 encoding heregulin under the control of the alkaline phosphatase promotor and



the STII leader sequence. In the initial characterization of heregulin activity, the precise natural amino and carboxy termini of the heregulin molecule were not precisely defined. However, after comparison of heregulin to EGF and TGF- $\alpha$  sequences, we expected that shortened forms of heregulin starting around Ser 221 and ending around Glu 277 of figure 4  
5 may have biological activity. Analogous regions of all heregulins may be identified and expressed. One shortened form was constructed to have an N-terminal Asp residue followed by the residues 221 to 277 of HRG- $\alpha$ . Due to an accidental frame shift mutation following Glu 277, HRG- $\alpha$  sequence was extended by 13 amino acids on the carboxy terminal end. Thus, the carboxy-terminal end was Glu 277 of HRG- $\alpha$  followed by the thirteen amino acid sequence  
10 RPNARLPPGVFYC (SEQ ID NO:20).

Expression of this construct was induced by growth of the cells in phosphate depleted medium for about 20 hours. Recombinant protein was purified by harvesting cell paste and resuspending in 10 mM Tris (pH8), homogenizing, incubating at 4°C. for 40 minutes and followed by centrifuging at 15 K rpm (Sorvall). The supernatant was concentrated on a 30K  
15 ultrafiltration membrane (Amicon) and the filtrate was applied to a MonoQ column equilibrated in 10 mM Tris pH8. The flow-through fractions from the MonoQ column were adjusted to 0.05% TFA (trifluoroacetic acid) and subjected to C4 reversed phase HPLC. Elution was with a gradient of 10-25% acetonitrile in 0.1% TFA/H<sub>2</sub>O. The solvent was removed by lyophilization and purified protein was resuspended in 0.1% bovine serum albumin  
20 in phosphate buffered saline. Figure 10 depicts HER2 receptor autophosphorylation data with MCF-7 cells in response to the purified E. coli-derived protein. This material demonstrated full biological activity with an EC<sub>50</sub> of 0.8 nM. The purified material was also tested in the cell growth assays (Example 5) and was found to be a potent stimulator of cell growth.

The recombinant expression vector for synthesis of HRG- $\beta$ 1 was constructed in a  
25 manner similar to HRG- $\alpha$ . The expression vector contained DNA encoding HRG- $\beta$ 1 amino acids from Ser<sub>207</sub> through Leu<sub>273</sub> (Figure 4). This DNA encoding HRG- $\beta$ 1 was recombinantly spliced into the expression vector downstream from the alkaline phosphatase promoter and STII leader sequence. An additional serine residue was spliced on the carboxy terminus as a result of the recombinant construction process. The expression vector encoding HRG- $\beta$ 1 was  
30 used to transform *E. coli* and expressed in phosphate depleted medium. Induced *E. coli* were pelleted, resuspended in 10mM Tris (pH7.5) and sonicated. Cell debris was pelleted by centrifugation and the supernatant was filtered through a sterile filter before assay. The expression of HRG- $\beta$ 1 was confirmed by the detection of protein having the ability to stimulate autophosphorylation of the HER2 receptor in MCF-7 cells.

35 A similar expression vector was constructed as described for HRG- $\beta$ 1 (above) with a C terminal tyrosine residue instead of the serine residue. This vector was transformed into *E. coli* and expressed as before. Purification of this recombinant protein was achieved as described for recombinant HRG- $\alpha$ . Mass spectrometric analysis revealed that the purified protein consisted of forms which were shorter than expected. Amino acid sequencing showed

that the protein had the desired N-terminal residue (Ser) but it was found by mass spectrometry to be truncated at the C terminus. The majority (>80%) of the protein consisted of a form 51 amino acids long with a C terminal methionine (MET 271) (SEQ ID NO:9). A small amount of a shorter form (49 residues) truncated at VAL 269 was also detected. However, both the shortened forms showed full biological activity in the HER2 receptor autophosphorylation assay.

#### Example 8

#### ISOLATION OF HEREGULIN $\beta$ 2 and $\beta$ 3 VARIANTS

Heregulin- $\beta$ 2 and - $\beta$ 3 variants were isolated in order to obtain cDNA clones that extend further in the 5' direction. A specifically primed cDNA library was constructed in  $\lambda$ gt10 by employing the chemically synthesized antisense primer 3' CCTTCCCGTTCTTCTTCCTCGCTCC (SEQ ID NO:21). This primer is located between nucleotides 167-190 in the sequence of  $\lambda$ her16 (figure 4). The isolation of clone  $\lambda$ 5'her13 (not to be confused with  $\lambda$ her13) was achieved by hybridizing a synthetic DNA probe corresponding to the 5' end of  $\lambda$ her16 under high stringency conditions with the specifically primed cDNA library. The nucleotide sequence of  $\lambda$ 5'her13 is shown in figure 11 (SEQ ID NO:22). The 496 base pair nucleotide sequence of  $\lambda$ 5'her13 is homologous to the sequence of  $\lambda$ her16 between nucleotides 309-496 of  $\lambda$ 5'her13 and 3-190 of  $\lambda$ her16.  $\lambda$ 5'her13 extends by 102 amino acids the open reading frame of  $\lambda$ her16.

The isolation of variant heregulin- $\beta$  forms was accomplished by probing a newly prepared oligodT primed  $\lambda$ gt10 MDA-MB-231 mRNA-derived cDNA library with synthetic probes corresponding to the 5' end of  $\lambda$ 5'her13 and the cysteine rich EGF-like region of  $\lambda$ her16. Three variants of heregulin- $\beta$  were identified, isolated and sequenced. The amino acid homologies between all heregulins is shown in figure 15 (SEQ ID NOS:26-30).

HRG polypeptides  $\lambda$ her76 (heregulin- $\beta$ 2) (SEQ ID NO:23),  $\lambda$ her78 (heregulin- $\beta$ 3) (SEQ ID NO:24) and  $\lambda$ her84 (heregulin  $\beta$ 2-like) (SEQ ID NO:25) are considered variants of  $\lambda$ her11.1db1 (heregulin- $\beta$ 1) because although the deduced amino acid sequence is identical between cysteine 1 and cysteine 6 of the EGF-like motif their sequences diverge before the predicted transmembrane domain which probably begins with amino acid 248 in  $\lambda$ her11.1db1.

The nucleotide sequences and deduced amino acid sequences of  $\lambda$ her76,  $\lambda$ her78 and  $\lambda$ her84 are shown in figures 12, 13 and 14.

The variants each contain a TGA stop codon 148 bases 5' of the first methionine codon in their sequences. Therefore the ATG codon at nucleotide position 135-137 of  $\lambda$ her16 and the corresponding ATG in the other heregulin clones may be defined as the initiating methionine (amino acid 1). Clones  $\lambda$ her11.1db1,  $\lambda$ her76,  $\lambda$ her84 and  $\lambda$ her78 all encode glutamine at amino acid 38 (Figure 15) whereas clone her16 encodes arginine (Figure 4, position 82).

The deduced amino acid sequence of  $\lambda$ her76 (heregulin- $\beta$ 1) reveals a full-length clone encoding 637 amino acids. It shares an identical deduced amino acid sequence as  $\lambda$ her11.1db1

except that residues corresponding to amino acids 232-239 of  $\lambda$ her11.1db1 have been deleted. The deduced amino acid sequence of  $\lambda$ her84 shows that it possesses the same amino acid sequence as  $\lambda$ her76 from the initiating methionine (amino acid 1, Figure 15) through the EGF-like area and transmembrane domain. However,  $\lambda$ her84 comes to an early stop codon at arginine 421 ( $\lambda$ her84 numbering). Thereafter the 3' untranslated sequence diverges. The deduced amino acid sequence of  $\lambda$ her78 (heregulin- $\beta^3$ ) is homologous with heregulins- $\beta^1$  and - $\beta^2$  through amino acid 230 where the sequence diverges for eleven amino acids then terminates. Thus heregulin- $\beta^3$  has no transmembrane region. The 3' untranslated sequence is not homologous to the other clones.

#### Example 9

##### EXPRESSION OF HEREGULIN $\beta$ FORMS

In order to express heregulin- $\beta$  forms in mammalian cells, full-length cDNA nucleotide sequences from  $\lambda$ her76 (heregulin- $\beta^2$ ) or  $\lambda$ her84 were subcloned into the mammalian expression vector pRK5.1. This vector is a derivative of pRK5 that contains a cytomegalovirus promoter followed by a 5' intron, a cloning polylinker and an SV40 early polyadenylation signal. COS7, monkey or human kidney 293 cells were transfected and conditioned medium was assayed in the MCF-7 cell p185/her2 autophosphorylation assay. A positive response confirmed the expression of the cDNA's from  $\lambda$ her76 (heregulin- $\beta^2$ ) and  $\lambda$ her84 (heregulin- $\beta^3$ ).

Supernatants from a large scale transient expression experiment were concentrated on a YM10 membrane (Amicon) and applied to a heparin Sepharose column as described in Example 1. Activity (tyrosine phosphorylation assay) was detected in the 0.6M NaCl elution pool and was further purified on a polyaspartic acid column, as previously described. By SDS gel analysis and activity assays, the active fractions of this column were highly purified and contained a single band of protein with an apparent molecular weight of 45,000 daltons. Thus, the expressed protein has chromatographic and structural properties which are very similar to those of the native form of heregulin originally isolated from the MDA 231 cells. Small scale transient expression experiments with constructs made from  $\lambda$ her84 cDNA also revealed comparable levels of activity in the cell supernatants from this variant form. The expression of the transmembrane-minus variant, heregulin- $\beta^3$ , is currently under investigation.

#### Example 10

proHRG- $\alpha$  and proHRG- $\beta^1$  cDNAs were spliced into Epstein Barr virus derived expression vectors containing a cytomegalovirus promoter. rHRGs were purified (essentially as described in Example 2) from the serum free conditioned medium of stably transfected CEN4 cells [human kidney 293 cells (ATCC No. 1573) expressing the Epstein Barr virus EBNA-1 transactivator. In other experiments full length proHRG- $\alpha$ , - $\beta^1$  and - $\beta^2$  transient expression constructs provided p185<sup>HER2</sup> phosphorylation activity in the conditioned medium of transfected COS7 monkey kidney cells. However, similar constructs of full length proHRG- $\beta^3$  failed to yield activity suggesting that the hydrophobic domain missing in proHRG- $\beta^3$  but

present in the other proHRGs is necessary for secretion of mature protein. Truncated versions of proHRG- $\alpha$  (63 amino acids, serin 177 to tyrosine 239) and proHRG- $\beta_1$  (68 amino acids, serine 177 to tyrosine 241) each encoding the GFD structural unit and immediate flanking regions were also expressed in *E. coli*; homologous truncated versions of HRG- $\beta_3$  are expected to be expressed as active molecules. These truncated proteins were purified from the periplasmic space and culture broth of *E. coli*. transformed with expression vectors designed to secrete recombinant proteins (C.N. Change, M. Rey, B. Bochenr, H. Heyneker, G. Gray, *Gene*, 55:189 [1987]). These proteins also stimulated tyrosine phosphorylation of p185<sup>HER2</sup> but not p107<sup>HER1</sup>, indicating that the biological activity of HRG resides in the EGF-like domain of the protein and that carbohydrate moieties are not essential for activity in this assay. The NTD does not inhibit or suppress this activity.

#### Example 11

Various human tissues were examined for the presence of HRG mRNA. Transcripts were found in breast, ovary, testis, prostate, heart, skeletal muscle, lung, liver, kidney, salivary gland, small intestine, and spleen but not in stomach, pancreas, uterus or placenta. While most of these tissues display the same three classes of transcripts as the MDA-MB-231 cells (6.6 kb, 2.5 kb and 1.8 kb), only the 6.6 kb message was observed for in heart and skeletal muscle. In brain a single transcript of 2.2 kb is observed and in testis the 6.6 kb transcript appears along with others of 2.2 kb, 1.9 kb and 1.5 kb. The tissue specific expression pattern observed for HRG differs from that of p185<sup>HER2</sup>; for example, adult liver, spleen, and brain contain HRG but not p185<sup>HER2</sup> transcripts whereas stomach, pancreas, uterus and placenta contain p185<sup>HER2</sup> transcripts but lack HRG mRNA.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

- 5       (i) APPLICANT: Genentech, Inc.
- (ii) TITLE OF INVENTION: Structure, Production and Use of Heregulin
- 10       (iii) NUMBER OF SEQUENCES: 30
- (iv) CORRESPONDENCE ADDRESS:
- (A) ADDRESSEE: Genentech, Inc.
- (B) STREET: 460 Point San Bruno Blvd
- 15       (C) CITY: South San Francisco
- (D) STATE: California
- (E) COUNTRY: USA
- (F) ZIP: 94080
- 20       (v) COMPUTER READABLE FORM:
- (A) MEDIUM TYPE: 5.25 inch, 360 Kb floppy disk
- (B) COMPUTER: IBM PC compatible
- (C) OPERATING SYSTEM: PC-DOS/MS-DOS
- (D) SOFTWARE: patin (Genentech)
- 25       (vi) CURRENT APPLICATION DATA:
- (A) APPLICATION NUMBER:
- (B) FILING DATE: 21-May-1992
- (C) CLASSIFICATION:
- 30       (vii) PRIOR APPLICATION DATA:
- (A) APPLICATION NUMBER:
- (B) FILING DATE: 11-May-1992
- 35       (vii) PRIOR APPLICATION DATA:
- (A) APPLICATION NUMBER: 07/847743
- (B) FILING DATE: 06-Mar-1992
- 40       (vii) PRIOR APPLICATION DATA:
- (A) APPLICATION NUMBER: 07/705256
- (B) FILING DATE: 24-May-1991
- 45       (vii) PRIOR APPLICATION DATA:
- (A) APPLICATION NUMBER: 07/765212
- (B) FILING DATE: 25-Sep-1991
- 50       (vii) PRIOR APPLICATION DATA:
- (A) APPLICATION NUMBER: 07/790801
- (B) FILING DATE: 08-Nov-1991
- 50       (viii) ATTORNEY/AGENT INFORMATION:
- (A) NAME: Hensley, Max D.
- (B) REGISTRATION NUMBER: 27,043
- (C) REFERENCE/DOCKET NUMBER: 712P4
- 55       (ix) TELECOMMUNICATION INFORMATION:
- (A) TELEPHONE: 415/266-1994
- (B) TELEFAX: 415/952-9881
- (C) TELEX: 910/371-7168

64

## (2) INFORMATION FOR SEQ ID NO:1:

## (i) SEQUENCE CHARACTERISTICS:

5

- (A) LENGTH: 6 bases
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

10

CNCAAT 6

15

## (2) INFORMATION FOR SEQ ID NO:2:

## (i) SEQUENCE CHARACTERISTICS:

20

- (A) LENGTH: 6 bases
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

25

AATAAA 6

30

## (2) INFORMATION FOR SEQ ID NO:3:

## (i) SEQUENCE CHARACTERISTICS:

35

- (A) LENGTH: 24 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

40 Ala Ala Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu Xaa  
1 5 10 15

Phe Met Val Lys Asp Leu Xaa Asn Pro  
20 24

45

## (2) INFORMATION FOR SEQ ID NO:4:

## (i) SEQUENCE CHARACTERISTICS:

50

- (A) LENGTH: 21 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

55 Xaa Glu Xaa Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys Lys Lys  
1 5 10 15

Glu Xaa Gly Xaa Gly Lys  
20 21

60

65

## (2) INFORMATION FOR SEQ ID NO:5:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 13 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Ala Glu Lys Glu Lys Thr Phe Xaa Val Asn Gly Gly Glu  
 1 5 10 13

## (2) INFORMATION FOR SEQ ID NO:6:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 42 bases  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

GCTGAGAAGG AGAAGACCTT CTGTCGTGAA TCGGACGGCG AG 42

## (2) INFORMATION FOR SEQ ID NO:7:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 2199 bases  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

GG GAC AAA CTT TTC CCA AAC CCG ATC CGA GCC CTT GGA 38  
 Asp Lys Leu Phe Pro Asn Pro Ile Arg Ala Leu Gly  
 1 5 10

CCA AAC TCG CCT GCG CCG AGA GCC GTC CGC GTA GAG CGC 77  
 Pro Asn Ser Pro Ala Pro Arg Ala Val Arg Val Glu Arg  
 15 20 25

TCC GTC TCC GGC GAG ATG TCC GAG CGC AAA GAA GGC AGA 116  
 Ser Val Ser Gly Glu Met Ser Glu Arg Lys Glu Gly Arg  
 30 35

GGC AAA GGG AAG GGC AAG AAG AAG GAG CGA GGC TCC GGC 155  
 Gly Lys Gly Lys Gly Lys Lys Lys Glu Arg Gly Ser Gly  
 40 45 50

AAG AAG CCG GAG TCC GCG GCG GGC AGC CAG AGC CCA GCC 194  
 Lys Lys Pro Glu Ser Ala Ala Gly Ser Gln Ser Pro Ala  
 55 60

TTG CCT CCC CAA TTG AAA GAG ATG AAA AGC CAG GAA TCG 233  
 Leu Pro Pro Gln Leu Lys Glu Met Lys Ser Gln Glu Ser  
 65 70 75

66

	GCT GCA GGT TCC AAA CTA GTC CTT CGG TGT GAA ACC AGT 272
	Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr Ser 90
5	TCT GAA TAC TCC TCT CTC AGA TTC AAG TGG TTC AAG AAT 311
	Ser Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys Asn 100
10	GGG AAT GAA TTG AAT CGA AAA AAC AAA CCA CAA AAT ATC 350
	Gly Asn Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile 115
15	AAG ATA CAA AAA AAG CCA GGG AAG TCA GAA CTT CGC ATT 389
	Lys Ile Gln Lys Lys Pro Gly Lys Ser Glu Leu Arg Ile 125
20	AAC AAA GCA TCA CTG GCT GAT TCT GGA GAG TAT ATG TGC 428
	Asn Lys Ala Ser Leu Ala Asp Ser Gly Glu Tyr Met Cys 140
25	AAA GTG ATC AGC AAA TTA GGA AAT GAC AGT GCC TCT GCC 467
	Lys Val Ile Ser Lys Leu Gly Asn Asp Ser Ala Ser Ala 155
30	AAT ATC ACC ATC GTG GAA TCA AAC GAG ATC ATC ACT GGT 506
	Asn Ile Thr Ile Val Glu Ser Asn Glu Ile Ile Thr Gly 165
35	ATG CCA GCC TCA ACT GAA GGA GCA TAT GTG TCT TCA GAG 545
	Met Pro Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser Glu 180
40	TCT CCC ATT AGA ATA TCA GTA TCC ACA GAA GGA GCA AAT 584
	Ser Pro Ile Arg Ile Ser Val Ser Thr Glu Gly Ala Asn 190
45	ACT TCT TCA TCT ACA TCT ACA TCC ACC ACT GGG ACA AGC 623
	Thr Ser Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr Ser 205
50	CAT CTT GTA AAA TGT GCG GAG AAG GAG AAA ACT TTC TGT 662
	His Leu Val Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys 220
55	GTG AAT GGA GGG GAG TGC TTC ATG GTG AAA GAC CTT TCA 701
	Val Asn Gly Gly Glu Cys Phe Met Val Lys Asp Leu Ser 230
60	AAC CCC TCG AGA TAC TTG TGC AAG TGC CCA AAT GAG TTT 740
	Asn Pro Ser Arg Tyr Leu Cys Lys Cys Pro Asn Glu Phe 245
	ACT GGT GAT CGC TGC CAA AAC TAC GTA ATG GCC AGC TTC 779
	Thr Gly Asp Arg Cys Gln Asn Tyr Val Met Ala Ser Phe 255
	TAC AAG CAT CTT GGG ATT GAA TTT ATG GAG GCG GAG GAG 818
	Tyr Lys His Leu Gly Ile Glu Phe Met Glu Ala Glu Glu 270
	CTG TAC CAG AAG AGA GTG CTG ACC ATA ACC GGC ATC TGC 857
	Leu Tyr Gln Lys Arg Val Leu Thr Ile Thr Gly Ile Cys 285



67

	ATC	GCC	CTC	CTT	GTG	GTC	GGC	ATC	ATG	TGT	GTG	GTG	GCC	896
	Ile	Ala	Leu	Leu	Val	Val	Gly	Ile	Met	Cys	Val	Val	Ala	
					290					295				
5	TAC	TGC	AAA	ACC	AAG	AAA	CAG	CGG	AAA	AAG	CTG	CAT	GAC	935
	Tyr	Cys	Lys	Thr	Lys	Lys	Gln	Arg	Lys	Lys	Leu	His	Asp	
		300					305					310		
10	CGT	CTT	CGG	CAG	AGC	CTT	CGG	TCT	GAA	CGA	AAC	AAT	ATG	974
	Arg	Leu	Arg	Gln	Ser	Leu	Arg	Ser	Glu	Arg	Asn	Asn	Met	
				315					320					
15	ATG	AAC	ATT	GCC	AAT	GGG	CCT	CAC	CAT	CCT	AAC	CCA	CCC	1013
	Met	Asn	Ile	Ala	Asn	Gly	Pro	His	His	Pro	Asn	Pro	Pro	
	325					330					335			
20	CCC	GAG	AAT	GTC	CAG	CTG	GTG	AAT	CAA	TAC	GTA	TCT	AAA	1052
	Pro	Glu	Asn	Val	Gln	Leu	Val	Asn	Gln	Tyr	Val	Ser	Lys	
			340					345					350	
25	AAC	GTC	ATC	TCC	AGT	GAG	CAT	ATT	GTT	GAG	AGA	GAA	GCA	1091
	Asn	Val	Ile	Ser	Ser	Glu	His	Ile	Val	Glu	Arg	Glu	Ala	
					355					360				
30	GAG	ACA	TCC	TTT	TCC	ACC	AGT	CAC	TAT	ACT	TCC	ACA	GCC	1130
	Glu	Thr	Ser	Phe	Ser	Thr	Ser	His	Tyr	Thr	Ser	Thr	Ala	
		365					370					375		
35	CAT	CAC	TCC	ACT	ACT	GTC	ACC	CAG	ACT	CCT	AGC	CAC	AGC	1169
	His	His	Ser	Thr	Thr	Val	Thr	Gln	Thr	Pro	Ser	His	Ser	
				380					385					
40	TGG	AGC	AAC	GGA	CAC	ACT	GAA	AGC	ATC	CTT	TCC	GAA	AGC	1208
	Trp	Ser	Asn	Gly	His	Thr	Glu	Ser	Ile	Leu	Ser	Glu	Ser	
	390					395					400			
45	CAC	TCT	GTA	ATC	GTG	ATG	TCA	TCC	GTA	GAA	AAC	AGT	AGG	1247
	His	Ser	Val	Ile	Val	Met	Ser	Ser	Val	Glu	Asn	Ser	Arg	
			405					410					415	
50	CAC	AGC	AGC	CCA	ACT	GGG	GGC	CCA	AGA	GGA	CGT	CTT	AAT	1286
	His	Ser	Ser	Pro	Thr	Gly	Gly	Pro	Arg	Gly	Arg	Leu	Asn	
				420						425				
55	GGC	ACA	GGA	GGC	CCT	CGT	GAA	TGT	AAC	AGC	TTC	CTC	AGG	1325
	Gly	Thr	Gly	Gly	Pro	Arg	Glu	Cys	Asn	Ser	Phe	Leu	Arg	
		430					435					440		
60	CAT	GCC	AGA	GAA	ACC	CCT	GAT	TCC	TAC	CGA	GAC	TCT	CCT	1364
	His	Ala	Arg	Glu	Thr	Pro	Asp	Ser	Tyr	Arg	Asp	Ser	Pro	
				445					450					
65	CAT	AGT	GAA	AGG	TAT	GTG	TCA	GCC	ATG	ACC	ACC	CCG	GCT	1403
	His	Ser	Glu	Arg	Tyr	Val	Ser	Ala	Met	Thr	Thr	Pro	Ala	
	455					460					465			
70	CGT	ATG	TCA	CCT	GTA	GAT	TTC	CAC	ACG	CCA	AGC	TCC	CCC	1442
	Arg	Met	Ser	Pro	Val	Asp	Phe	His	Thr	Pro	Ser	Ser	Pro	
			470					475					480	
75	AAA	TCG	CCC	CCT	TCG	GAA	ATG	TCT	CCA	CCC	GTG	TCC	AGC	1481
	Lys	Ser	Pro	Pro	Ser	Glu	Met	Ser	Pro	Pro	Val	Ser	Ser	
					485						490			

68

ATG ACG GTG TCC ATG CCT TCC ATG GCG GTC AGC CCC TTC 1520  
 Met Thr Val Ser Met Pro Ser Met Ala Val Ser Pro Phe  
 495 500 505

5 ATG GAA GAA GAG AGA CCT CTA CTT CTC GTG ACA CCA CCA 1559  
 Met Glu Glu Glu Arg Pro Leu Leu Leu Val Thr Pro Pro  
 510 515

10 AGG CTG CGG GAG AAG AAG TTT GAC CAT CAC CCT CAG CAG 1598  
 Arg Leu Arg Glu Lys Lys Phe Asp His His Pro Gln Gln  
 520 525 530

15 TTC AGC TCC TTC CAC CAC AAC CCC GCG CAT GAC AGT AAC 1637  
 Phe Ser Ser Phe His His Asn Pro Ala His Asp Ser Asn  
 535 540 545

AGC CTC CCT GCT AGC CCC TTG AGG ATA GTG GAG GAT GAG 1676  
 Ser Leu Pro Ala Ser Pro Leu Arg Ile Val Glu Asp Glu  
 550 555

20 GAG TAT GAA ACG ACC CAA GAG TAC GAG CCA GCC CAA GAG 1715  
 Glu Tyr Glu Thr Thr Gln Glu Tyr Glu Pro Ala Gln Glu  
 560 565 570

25 CCT GTT AAG AAA CTC GCC AAT AGC CGG CGG GCC AAA AGA 1754  
 Pro Val Lys Lys Leu Ala Asn Ser Arg Arg Ala Lys Arg  
 575 580

30 ACC AAG CCC AAT GGC CAC ATT GCT AAC AGA TTG GAA GTG 1793  
 Thr Lys Pro Asn Gly His Ile Ala Asn Arg Leu Glu Val  
 585 590 595

35 GAC AGC AAC ACA AGC TCC CAG AGC AGT AAC TCA GAG AGT 1832  
 Asp Ser Asn Thr Ser Ser Gln Ser Ser Asn Ser Glu Ser  
 600 605 610

GAA ACA GAA GAT GAA AGA GTA GGT GAA GAT ACG CCT TTC 1871  
 Glu Thr Glu Asp Glu Arg Val Gly Glu Asp Thr Pro Phe  
 615 620

40 CTG GGC ATA CAG AAC CCC CTG GCA GCC AGT CTT GAG GCA 1910  
 Leu Gly Ile Gln Asn Pro Leu Ala Ala Ser Leu Glu Ala  
 625 630 635

45 ACA CCT GCC TTC CGC CTG GCT GAC AGC AGG ACT AAC CCA 1949  
 Thr Pro Ala Phe Arg Leu Ala Asp Ser Arg Thr Asn Pro  
 640 645

50 GCA GGC CGC TTC TCG ACA CAG GAA GAA ATC CAG GCC AGG 1988  
 Ala Gly Arg Phe Ser Thr Gln Glu Glu Ile Gln Ala Arg  
 650 655 660

55 CTG TCT AGT GTA ATT GCT AAC CAA GAC CCT ATT GCT GTA TA 2029  
 Leu Ser Ser Val Ile Ala Asn Gln Asp Pro Ile Ala Val  
 665 670 675

A AACCTAAATA AACACATAGA TTCACCTGTA AAACCTTTATT 2070

60 TTATATAATA AAGTATTCCA CCTTAAATTA AACAATTTAT TTTATTTTAG 2120

CAGTCTGCA AATAGAAAAC AGGAAAAAAA CTTTTATAAA TTAAATATAT 2170

GTATGTAAAA ATGAAAAAAA AAAAAAAAAA 2199

5

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

10

(A) LENGTH: 669 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

15	Ala Arg Ala Pro Gln Arg Gly Arg Ser Leu Ser Pro Ser Arg Asp	1	5	10	15
	Lys Leu Phe Pro Asn Pro Ile Arg Ala Leu Gly Pro Asn Ser Pro	20	25	30	
20	Ala Pro Arg Ala Val Arg Val Glu Arg Ser Val Ser Gly Glu Met	35	40	45	
	Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys Lys Lys	50	55	60	
25	Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala Ala Gly Ser Gln	65	70	75	
30	Ser Pro Ala Leu Pro Pro Arg Leu Lys Glu Met Lys Ser Gln Glu	80	85	90	
	Ser Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr Ser Ser	95	100	105	
35	Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys Asn Gly Asn Glu	110	115	120	
	Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys Lys	125	130	135	
40	Pro Gly Lys Ser Glu Leu Arg Ile Asn Lys Ala Ser Leu Ala Asp	140	145	150	
45	Ser Gly Glu Tyr Met Cys Lys Val Ile Ser Lys Leu Gly Asn Asp	155	160	165	
	Ser Ala Ser Ala Asn Ile Thr Ile Val Glu Ser Asn Glu Ile Ile	170	175	180	
50	Thr Gly Met Pro Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser Glu	185	190	195	
	Ser Pro Ile Arg Ile Ser Val Ser Thr Glu Gly Ala Asn Thr Ser	200	205	210	
55	Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr Ser His Leu Val Lys	215	220	225	
60	Cys Ala Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu Cys	230	235	240	
	Phe Met Val Lys Asp Leu Ser Asn Pro Ser Arg Tyr Leu Cys Lys	245	250	255	

	Cys	Gln	Pro	Gly	Phe	Thr	Gly	Ala	Arg	Cys	Thr	Glu	Asn	Val	Pro
					260					265					270
5	Met	Lys	Val	Gln	Asn	Gln	Glu	Lys	Ala	Glu	Glu	Leu	Tyr	Gln	Lys
					275					280					285
	Arg	Val	Leu	Thr	Ile	Thr	Gly	Ile	Cys	Ile	Ala	Leu	Leu	Val	Val
					290					295					300
10	Gly	Ile	Met	Cys	Val	Val	Ala	Tyr	Cys	Lys	Thr	Lys	Lys	Gln	Arg
					305					310					315
	Lys	Lys	Leu	His	Asp	Arg	Leu	Arg	Gln	Ser	Leu	Arg	Ser	Glu	Arg
15					320					325					330
	Asn	Asn	Met	Met	Asn	Ile	Ala	Asn	Gly	Pro	His	His	Pro	Asn	Pro
					335					340					345
20	Pro	Pro	Glu	Asn	Val	Gln	Leu	Val	Asn	Gln	Tyr	Val	Ser	Lys	Asn
					350					355					360
	Val	Ile	Ser	Ser	Glu	His	Ile	Val	Glu	Arg	Glu	Ala	Glu	Thr	Ser
					365					370					375
25	Phe	Ser	Thr	Ser	His	Tyr	Thr	Ser	Thr	Ala	His	His	Ser	Thr	Thr
					380					385					390
	Val	Thr	Gln	Thr	Pro	Ser	His	Ser	Trp	Ser	Asn	Gly	His	Thr	Glu
30					395					400					405
	Ser	Ile	Leu	Ser	Glu	Ser	His	Ser	Val	Ile	Val	Met	Ser	Ser	Val
					410					415					420
35	Glu	Asn	Ser	Arg	His	Ser	Ser	Pro	Thr	Gly	Gly	Pro	Arg	Gly	Arg
					425					430					435
	Leu	Asn	Gly	Thr	Gly	Gly	Pro	Arg	Glu	Cys	Asn	Ser	Phe	Leu	Arg
					440					445					450
40	His	Ala	Arg	Glu	Thr	Pro	Asp	Ser	Tyr	Arg	Asp	Ser	Pro	His	Ser
					455					460					465
	Glu	Arg	Tyr	Val	Ser	Ala	Met	Thr	Thr	Pro	Ala	Arg	Met	Ser	Pro
45					470					475					480
	Val	Asp	Phe	His	Thr	Pro	Ser	Ser	Pro	Lys	Ser	Pro	Pro	Ser	Glu
					485					490					495
50	Met	Ser	Pro	Pro	Val	Ser	Ser	Met	Thr	Val	Ser	Met	Pro	Ser	Met
					500					505					510
	Ala	Val	Ser	Pro	Phe	Met	Glu	Glu	Glu	Arg	Pro	Leu	Leu	Leu	Val
					515					520					525
55	Thr	Pro	Pro	Arg	Leu	Arg	Glu	Lys	Lys	Phe	Asp	His	His	Pro	Gln
					530					535					540
	Gln	Phe	Ser	Ser	Phe	His	His	Asn	Pro	Ala	His	Asp	Ser	Asn	Ser
60					545					550					555
	Leu	Pro	Ala	Ser	Pro	Leu	Arg	Ile	Val	Glu	Asp	Glu	Glu	Tyr	Glu
					560					565					570

71

Thr Thr Gln Glu Tyr Glu Pro Ala Gln Glu Pro Val Lys Lys Leu  
575 580 585

5 Ala Asn Ser Arg Arg Ala Lys Arg Thr Lys Pro Asn Gly His Ile  
590 595 600

Ala Asn Arg Leu Glu Val Asp Ser Asn Thr Ser Ser Gln Ser Ser  
605 610 615

10 Asn Ser Glu Ser Glu Thr Glu Asp Glu Arg Val Gly Glu Asp Thr  
620 625 630

Pro Phe Leu Gly Ile Gln Asn Pro Leu Ala Ala Ser Leu Glu Ala  
635 640 645

15 Thr Pro Ala Phe Arg Leu Ala Asp Ser Arg Thr Asn Pro Ala Gly  
650 655 660

20 Arg Phe Ser Thr Gln Glu Glu Ile Gln  
665 669

## (2) INFORMATION FOR SEQ ID NO:9:

25 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 732 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

30 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

35 Asp Lys Leu Phe Pro Asn Pro Ile Arg Ala Leu Gly Pro Asn Ser  
1 5 10 15

Pro Ala Pro Arg Ala Val Arg Val Glu Arg Ser Val Ser Gly Glu  
20 25 30

Met Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys Lys  
35 40 45

40 Lys Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala Ala Gly Ser  
50 55 60

Gln Ser Pro Ala Leu Pro Pro Gln Leu Lys Glu Met Lys Ser Gln  
65 70 75

45 Glu Ser Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr Ser  
80 85 90

50 Ser Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys Asn Gly Asn  
95 100 105

Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys  
110 115 120

55 Lys Pro Gly Lys Ser Glu Leu Arg Ile Asn Lys Ala Ser Leu Ala  
125 130 135

Asp Ser Gly Glu Tyr Met Cys Lys Val Ile Ser Lys Leu Gly Asn  
140 145 150

60 Asp Ser Ala Ser Ala Asn Ile Thr Ile Val Glu Ser Asn Glu Ile  
155 160 165

Ile Thr Gly Met Pro Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser

72

		170		175		180	
		Glu Ser Pro Ile Arg Ile Ser Val Ser Thr Glu Gly Ala Asn Thr		Thr Glu Gly Ala Asn Thr			
		185		190		195	
5		Ser Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr Ser His Leu Val		Gly Thr Ser His Leu Val			
		200		205		210	
10		Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu		Cys Val Asn Gly Gly Glu			
		215		220		225	
		Cys Phe Met Val Lys Asp Leu Ser Asn Pro Ser Arg Tyr Leu Cys		Pro Ser Arg Tyr Leu Cys			
		230		235		240	
15		Lys Cys Pro Asn Glu Phe Thr Gly Asp Arg Cys Gln Asn Tyr Val		Arg Cys Gln Asn Tyr Val			
		245		250		255	
		Met Ala Ser Phe Tyr Lys His Leu Gly Ile Glu Phe Met Glu Ala		Ile Glu Phe Met Glu Ala			
		260		265		270	
20		Glu Glu Leu Tyr Gln Lys Arg Val Leu Thr Ile Thr Gly Ile Cys		Thr Ile Thr Gly Ile Cys			
		275		280		285	
25		Ile Ala Leu Leu Val Val Gly Ile Met Cys Val Val Ala Tyr Cys		Cys Val Val Ala Tyr Cys			
		290		295		300	
		Lys Thr Lys Lys Gln Arg Lys Lys Leu His Asp Arg Leu Arg Gln		His Asp Arg Leu Arg Gln			
		305		310		315	
30		Ser Leu Arg Ser Glu Arg Asn Asn Met Met Asn Ile Ala Asn Gly		Met Asn Ile Ala Asn Gly			
		320		325		330	
		Pro His His Pro Asn Pro Pro Pro Glu Asn Val Gln Leu Val Asn		Asn Val Gln Leu Val Asn			
		335		340		345	
35		Gln Tyr Val Ser Lys Asn Val Ile Ser Ser Glu His Ile Val Glu		Ser Glu His Ile Val Glu			
		350		355		360	
40		Arg Glu Ala Glu Thr Ser Phe Ser Thr Ser His Tyr Thr Ser Thr		Ser His Tyr Thr Ser Thr			
		365		370		375	
		Ala His His Ser Thr Thr Val Thr Gln Thr Pro Ser His Ser Trp		Thr Pro Ser His Ser Trp			
		380		385		390	
45		Ser Asn Gly His Thr Glu Ser Ile Leu Ser Glu Ser His Ser Val		Ser Glu Ser His Ser Val			
		395		400		405	
		Ile Val Met Ser Ser Val Glu Asn Ser Arg His Ser Ser Pro Thr		Arg His Ser Ser Pro Thr			
		410		415		420	
50		Gly Gly Pro Arg Gly Arg Leu Asn Gly Thr Gly Gly Pro Arg Glu		Thr Gly Gly Pro Arg Glu			
		425		430		435	
		Cys Asn Ser Phe Leu Arg His Ala Arg Glu Thr Pro Asp Ser Tyr		Glu Thr Pro Asp Ser Tyr			
		440		445		450	
55		Arg Asp Ser Pro His Ser Glu Arg Tyr Val Ser Ala Met Thr Thr		Val Ser Ala Met Thr Thr			
		455		460		465	
60		Pro Ala Arg Met Ser Pro Val Asp Phe His Thr Pro Ser Ser Pro		His Thr Pro Ser Ser Pro			
		470		475		480	
		Lys Ser Pro Pro Ser Glu Met Ser Pro Pro Val Ser Ser Met Thr		Pro Val Ser Ser Met Thr			
		485		490		495	

	Val Ser Met Pro Ser Met Ala Val Ser Pro Phe Met Glu Glu Glu	500	505	510
5	Arg Pro Leu Leu Leu Val Thr Pro Pro Arg Leu Arg Glu Lys Lys	515	520	525
	Phe Asp His His Pro Gln Gln Phe Ser Ser Phe His His Asn Pro	530	535	540
10	Ala His Asp Ser Asn Ser Leu Pro Ala Ser Pro Leu Arg Ile Val	545	550	555
	Glu Asp Glu Glu Tyr Glu Thr Thr Gln Glu Tyr Glu Pro Ala Gln	560	565	570
15	Glu Pro Val Lys Lys Leu Ala Asn Ser Arg Arg Ala Lys Arg Thr	575	580	585
	Lys Pro Asn Gly His Ile Ala Asn Arg Leu Glu Val Asp Ser Asn	590	595	600
	Thr Ser Ser Gln Ser Ser Asn Ser Glu Ser Glu Thr Glu Asp Glu	605	610	615
25	Arg Val Gly Glu Asp Thr Pro Phe Leu Gly Ile Gln Asn Pro Leu	620	625	630
	Ala Ala Ser Leu Glu Ala Thr Pro Ala Phe Arg Leu Ala Asp Ser	635	640	645
30	Arg Thr Asn Pro Ala Gly Arg Phe Ser Thr Gln Glu Glu Ile Gln	650	655	660
	Ala Arg Leu Ser Ser Val Ile Ala Asn Gln Asp Pro Ile Ala Val	665	670	675
	Xaa Asn Leu Asn Lys His Ile Asp Ser Pro Val Lys Leu Tyr Phe	680	685	690
40	Ile Xaa Xaa Ser Ile Pro Pro Xaa Ile Lys Gln Phe Ile Leu Phe	695	700	705
	Xaa Gln Phe Cys Lys Xaa Lys Thr Gly Lys Lys Leu Leu Xaa Ile	710	715	720
45	Lys Tyr Met Tyr Val Lys Met Lys Lys Lys Lys Lys	725	730	732

50 (2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 66 amino acids

(B) TYPE: amino acid

55 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

60	Ser His Leu Val Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val	1	5	10	15
	Asn Gly Gly Glu Cys Phe Met Val Lys Asp Leu Ser Asn Pro Ser	20	25	30	

Arg Tyr Leu Cys Lys Cys Gln Pro Gly Phe Thr Gly Ala Arg Cys  
35 40 45

**5** Thr Glu Asn Val Pro Met Lys Val Gln Asn Gln Glu Lys Ala Glu  
                    50                 55                 60

Glu Leu Tyr Gln Lys Arg  
65 66

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 71 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

20 Ser His Leu Val Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val  
1 5 10 15

Asn Gly Gly Glu Cys Phe Met Val Lys Asp Leu Ser Asn Pro Ser  
20 25 30

25 Arg Tyr Leu Cys Lys Cys Pro Asn Glu Phe Thr Gly Asp Arg Cys  
35 40 45

Gln Asn Tyr Val Met Ala Ser Phe Tyr Lys His Leu Gly Ile Glu  
50 55 60

30 Phe Met Glu Ala Glu Glu Leu Tyr Gln Lys Arg  
65 70 71

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 2010 bases  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

45 GGGCGCGAGC GCCTCAGCGC GGCCGCTCGC TCTCCCCCTC GAGGGACAAA 50

CTTTTCCCAA ACCCGATCCG AGCCCTTGGA CCAAAC TCGC CTGCGCCGAG 100

50 AGCCGTCCGC GTAGAGCGCT CCGTCTCCGG CGAGATGTCC GAGCGCAAAG 150

AAGGCAGAGG CAAAGGGAAG GGCAAGAAGA AGGAGCGAGG CTCCGGCAAG 200

55  
AAGCCGGAGT CCGCGGCGGG CAGCCAGAGC CCAGCCTTGC CTCCCCGATT 250

60 GAAAGAGATG AAAAGCCAGG AATCGGCTGC AGGTTCCAAA CTAGTCCTTC 300

GGTGTGAAC CAGTTCTGAA TACTCCTCTC TCAGATTCAA GTGGTTCAAG 350



AATGGGAATG AATTGAATCG AAAAAACAAA CCACAAAATA TCAAGATACA 400  
5 AAAAAAGCCA GGAAGTCAG AACTTCGCAT TAACAAAGCA TCACTGGCTG 450  
ATTCTGGAGA GTATATGTGC AAAGTGATCA GCAAATTAGG AAATGACAGT 500  
10 GCCTCTGCCA ATATCACCAT CGTGAATCA AACGAGATCA TCACTGGTAT 550  
GCCAGCCTCA ACTGAAGGAG CATATGTGTC TTCAGAGTCT CCCATTAGAA 600  
15 TATCAGTATC CACAGAAGGA GCAAATACTT CTTCATCTAC ATCTACATCC 650  
ACCACTGGGA CAAGCCATCT TGTAAATGT GCGGAGAAGG AGAAACTTT 700  
CTGTGTGAAT GGAGGGGAGT GCTTCATGGT GAAAGACCTT TCAAACCCCT 750  
25 CGAGATACTT GTGCAAGTGC CAACCTGGAT TCACTGGAGC AAGATGTACT 800  
GAGAATGTGC CCATGAAAGT CCAAACCAA GAAAAGGCGG AGGAGCTGTA 850  
30 CCAGAAGAGA GTGCTGACCA TAACCGGCAT CTGCATCGCC CTCCTTGTGG 900  
TCGGCATCAT GTGTGTGGTG GCCTACTGCA AAACCAAGAA ACAGCGGAAA 950  
AAGCTGCATG ACCGTCCTCG GCAGAGCCTT CGGTCTGAAC GAAACAATAT 1000  
40 GATGAACATT GCCAATGGGC CTCACCATCC TAACCCACCC CCCGAGAATG 1050  
TCCAGCTGGT GAATCAATAC GTATCTAAAA ACGTCATCTC CAGTGAGCAT 1100  
45 ATTGTTGAGA GAGAAGCAGA GACATCCTTT TCCACCAGTC ACTATACTTC 1150  
CACAGCCCAT CACTCCACTA CTGTCACCCA GACTCCTAGC CACAGCTGGA 1200  
GCAACGGACA CACTGAAAGC ATCCTTTCCG AAAGCCACTC TGTAATCGTG 1250  
55 ATGTCATCCG TAGAAAACAG TAGGCACAGC AGCCCAACTG GGGGCCCAAG 1300  
AGGACGTCTT AATGGCACAG GAGGCCCTCG TGAATGTAAC AGCTTCCTCA 1350  
60 GGCATGCCAG AGAAACCCCT GATTCTTACC GAGACTCTCC TCATAGTGAA 1400

76

AGGTATGTGT CAGCCATGAC CACCCCGGCT CGTATGTCAC CTGTAGATTT 1450  
 CCACACGCCA AGCTCCCCCA AATCGCCCCC TTCGAAATG TCTCCACCCG 1500  
 5 TGTCCAGCAT GACGGTGTCC ATGCCTTCCA TGGCGGTCAG CCCCTTCATG 1550  
 GAAGAAGAGA GACCTCTACT TCTCGTGACA CCACCAAGGC TGCGGGAGAA 1600  
 10 GAAGTTTGAC CATCACCTC AGCAGTTCAG CTCCTTCAC CACAACCCCG 1650  
 CGCATGACAG TAACAGCCTC CCTGCTAGCC CTTGAGGAT AGTGGAGGAT 1700  
 15 GAGGAGTATG AAACGACCCA AGAGTACGAG CCAGCCCAAG AGCCTGTTAA 1750  
 20 GAAACTCGCC AATAGCCGGC GGGCCAAAAG AACCAAGCCC AATGGCCACA 1800  
 TTGCTAACAG ATTGGAAGTG GACAGCAACA CAAGCTCCCA GAGCAGTAAC 1850  
 TCAGAGAGTG AAACAGAAGA TGAAAGAGTA GGTGAAGATA CGCCTTTCCT 1900  
 30 GGGCATAACAG AACCCCTGG CAGCCAGTCT TGAGGCAACA CCTGCCTTCC 1950  
 GCCTGGCTGA CAGCAGGACT AACCCAGCAG GCCGCTTCTC GACACAGGAA 2000  
 35 GAAATCCAGG 2010

40 (2) INFORMATION FOR SEQ ID NO:13:

45 (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 669 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

50 Ala Arg Ala Pro Gln Arg Gly Arg Ser Leu Ser Pro Ser Arg Asp  
     1                    5                    10                    15  
 Lys Leu Phe Pro Asn Pro Ile Arg Ala Leu Gly Pro Asn Ser Pro  
                     20                    25                    30  
 55 Ala Pro Arg Ala Val Arg Val Glu Arg Ser Val Ser Gly Glu Met  
                     35                    40                    45  
 Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys Lys Lys  
 60                    50                    55                    60  
 Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala Ala Gly Ser Gln  
                     65                    70                    75

77

	Ser	Pro	Ala	Leu	Pro	Pro	Arg	Leu	Lys	Glu	Met	Lys	Ser	Gln	Glu	80	85	90
5	Ser	Ala	Ala	Gly	Ser	Lys	Leu	Val	Leu	Arg	Cys	Glu	Thr	Ser	Ser	95	100	105
	Glu	Tyr	Ser	Ser	Leu	Arg	Phe	Lys	Trp	Phe	Lys	Asn	Gly	Asn	Glu	110	115	120
10	Leu	Asn	Arg	Lys	Asn	Lys	Pro	Gln	Asn	Ile	Lys	Ile	Gln	Lys	Lys	125	130	135
	Pro	Gly	Lys	Ser	Glu	Leu	Arg	Ile	Asn	Lys	Ala	Ser	Leu	Ala	Asp	140	145	150
15	Ser	Gly	Glu	Tyr	Met	Cys	Lys	Val	Ile	Ser	Lys	Leu	Gly	Asn	Asp	155	160	165
20	Ser	Ala	Ser	Ala	Asn	Ile	Thr	Ile	Val	Glu	Ser	Asn	Glu	Ile	Ile	170	175	180
	Thr	Gly	Met	Pro	Ala	Ser	Thr	Glu	Gly	Ala	Tyr	Val	Ser	Ser	Glu	185	190	195
25	Ser	Pro	Ile	Arg	Ile	Ser	Val	Ser	Thr	Glu	Gly	Ala	Asn	Thr	Ser	200	205	210
	Ser	Ser	Thr	Ser	Thr	Ser	Thr	Thr	Gly	Thr	Ser	His	Leu	Val	Lys	215	220	225
30	Cys	Ala	Glu	Lys	Glu	Lys	Thr	Phe	Cys	Val	Asn	Gly	Gly	Glu	Cys	230	235	240
35	Phe	Met	Val	Lys	Asp	Leu	Ser	Asn	Pro	Ser	Arg	Tyr	Leu	Cys	Lys	245	250	255
	Cys	Gln	Pro	Gly	Phe	Thr	Gly	Ala	Arg	Cys	Thr	Glu	Asn	Val	Pro	260	265	270
40	Met	Lys	Val	Gln	Asn	Gln	Glu	Lys	Ala	Glu	Glu	Leu	Tyr	Gln	Lys	275	280	285
	Arg	Val	Leu	Thr	Ile	Thr	Gly	Ile	Cys	Ile	Ala	Leu	Leu	Val	Val	290	295	300
45	Gly	Ile	Met	Cys	Val	Val	Ala	Tyr	Cys	Lys	Thr	Lys	Lys	Gln	Arg	305	310	315
50	Lys	Lys	Leu	His	Asp	Arg	Leu	Arg	Gln	Ser	Leu	Arg	Ser	Glu	Arg	320	325	330
	Asn	Asn	Met	Met	Asn	Ile	Ala	Asn	Gly	Pro	His	His	Pro	Asn	Pro	335	340	345
55	Pro	Pro	Glu	Asn	Val	Gln	Leu	Val	Asn	Gln	Tyr	Val	Ser	Lys	Asn	350	355	360
	Val	Ile	Ser	Ser	Glu	His	Ile	Val	Glu	Arg	Glu	Ala	Glu	Thr	Ser	365	370	375
60	Phe	Ser	Thr	Ser	His	Tyr	Thr	Ser	Thr	Ala	His	His	Ser	Thr	Thr	380	385	390
	Val	Thr	Gln	Thr	Pro	Ser	His	Ser	Trp	Ser	Asn	Gly	His	Thr	Glu			

78

	395	400	405
	Ser Ile Leu Ser Glu Ser His Ser Val	Ile Val Met Ser Ser Val	
	410	415	420
5	Glu Asn Ser Arg His Ser Ser Pro Thr	Gly Gly Pro Arg Gly Arg	
	425	430	435
	Leu Asn Gly Thr Gly Gly Pro Arg Glu	Cys Asn Ser Phe Leu Arg	
10	440	445	450
	His Ala Arg Glu Thr Pro Asp Ser Tyr	Arg Asp Ser Pro His Ser	
	455	460	465
15	Glu Arg Tyr Val Ser Ala Met Thr Thr	Pro Ala Arg Met Ser Pro	
	470	475	480
	Val Asp Phe His Thr Pro Ser Ser Pro	Lys Ser Pro Pro Ser Glu	
	485	490	495
20	Met Ser Pro Pro Val Ser Ser Met Thr	Val Ser Met Pro Ser Met	
	500	505	510
	Ala Val Ser Pro Phe Met Glu Glu Glu	Arg Pro Leu Leu Leu Val	
25	515	520	525
	Thr Pro Pro Arg Leu Arg Glu Lys Lys	Phe Asp His His Pro Gln	
	530	535	540
30	Gln Phe Ser Ser Phe His His Asn Pro	Ala His Asp Ser Asn Ser	
	545	550	555
	Leu Pro Ala Ser Pro Leu Arg Ile Val	Glu Asp Glu Glu Tyr Glu	
	560	565	570
35	Thr Thr Gln Glu Tyr Glu Pro Ala Gln	Glu Pro Val Lys Lys Leu	
	575	580	585
	Ala Asn Ser Arg Arg Ala Lys Arg Thr	Lys Pro Asn Gly His Ile	
40	590	595	600
	Ala Asn Arg Leu Glu Val Asp Ser Asn	Thr Ser Ser Gln Ser Ser	
	605	610	615
45	Asn Ser Glu Ser Glu Thr Glu Asp Glu	Arg Val Gly Glu Asp Thr	
	620	625	630
	Pro Phe Leu Gly Ile Gln Asn Pro Leu	Ala Ala Ser Leu Glu Ala	
	635	640	645
50	Thr Pro Ala Phe Arg Leu Ala Asp Ser	Arg Thr Asn Pro Ala Gly	
	650	655	660
	Arg Phe Ser Thr Gln Glu Glu Ile Gln		
55	665	669	

(2) INFORMATION FOR SEQ ID NO:14:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 95 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

60

79

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

Ser His Leu Val Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val  
 1 5 10 15  
 5 Asn Gly Gly Glu Cys Phe Met Val Lys Asp Leu Ser Asn Pro Ser  
 20 25 30  
 10 Arg Tyr Leu Cys Lys Cys Gln Pro Gly Phe Thr Gly Ala Arg Cys  
 35 40 45  
 Thr Glu Asn Val Pro Met Lys Val Gln Asn Gln Glu Lys Ala Glu  
 50 55 60  
 15 Glu Leu Tyr Gln Lys Arg Val Leu Thr Ile Thr Gly Ile Cys Ile  
 65 70 75  
 Ala Leu Leu Val Val Gly Ile Met Cys Val Val Ala Tyr Cys Lys  
 80 85 90  
 20 Thr Lys Lys Gln Arg  
 95

(2) INFORMATION FOR SEQ ID NO:15:

25

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 91 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

30

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

Asn Ser Asp Ser Glu Cys Pro Leu Ser His Asp Gly Tyr Cys Leu  
 1 5 10 15  
 35 His Asp Gly Val Cys Met Tyr Ile Glu Ala Leu Asp Lys Tyr Ala  
 20 25 30  
 40 Cys Asn Cys Val Val Gly Tyr Ile Gly Glu Arg Cys Gln Tyr Arg  
 35 40 45  
 Asp Leu Lys Trp Trp Glu Leu Arg His Ala Gly His Gly Gln Gln  
 50 55 60  
 45 Gln Lys Val Ile Val Val Ala Val Cys Val Val Val Leu Val Met  
 65 70 75  
 Leu Leu Leu Leu Ser Leu Trp Gly Ala His Tyr Tyr Arg Thr Gln  
 80 85 90  
 50 Lys  
 91

(2) INFORMATION FOR SEQ ID NO:16:

55

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 82 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

60

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

Asn Asp Cys Pro Asp Ser His Thr Gln Phe Cys Phe His Gly Thr  
 1 5 10 15

	Cys	Arg	Phe	Leu	Val	Gln	Glu	Asp	Lys	Pro	Ala	Cys	Val	Cys	His
					20					25					30
5	Ser	Gly	Tyr	Val	Gly	Ala	Arg	Cys	Glu	His	Ala	Asp	Leu	Leu	Ala
					35					40					45
	Val	Val	Ala	Ala	Ser	Gln	Lys	Lys	Gln	Ala	Ile	Thr	Ala	Leu	Val
					50					55					60
10	Val	Val	Ser	Ile	Val	Ala	Leu	Ala	Val	Leu	Ile	Ile	Thr	Cys	Val
					65					70					75
	Leu	Ile	His	Cys	Cys	Gln	Val								
15					80		82								

(2) INFORMATION FOR SEQ ID NO:17:

20 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 87 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

20	Lys	Lys	Lys	Asn	Pro	Cys	Asn	Ala	Glu	Phe	Gln	Asn	Phe	Cys	Ile
	1				5					10					15
30	His	Gly	Glu	Cys	Lys	Tyr	Ile	Glu	His	Leu	Glu	Ala	Val	Thr	Cys
					20					25					30
	Lys	Cys	Gln	Gln	Glu	Tyr	Phe	Gly	Glu	Arg	Cys	Gly	Glu	Lys	Ser
					35					40					45
35	Met	Lys	Thr	His	Ser	Met	Ile	Asp	Ser	Ser	Leu	Ser	Lys	Ile	Ala
					50					55					60
	Leu	Ala	Ala	Ile	Ala	Ala	Phe	Met	Ser	Ala	Val	Ile	Leu	Thr	Ala
					65					70					75
40	Val	Ala	Val	Ile	Thr	Val	Gln	Leu	Arg	Arg	Gln	Tyr			
					80					85		87			

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 87 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

55	Lys	Lys	Lys	Asn	Pro	Cys	Ala	Ala	Lys	Phe	Gln	Asn	Phe	Cys	Ile
	1				5					10					15
60	His	Gly	Glu	Cys	Arg	Tyr	Ile	Glu	Asn	Leu	Glu	Val	Val	Thr	Cys
					20					25					30
60	His	Cys	His	Gln	Asp	Tyr	Phe	Gly	Glu	Arg	Cys	Gly	Glu	Lys	Thr
					35					40					45
60	Met	Lys	Thr	Gln	Lys	Lys	Asp	Asp	Ser	Asp	Leu	Ser	Lys	Ile	Ala
					50					55					60

81

Leu Ala Ala Ile Ile Val Phe Val Ser Ala Val Ser Val Ala Ala  
                                 65                                70                                75

5     Ile Gly Ile Ile Thr Ala Val Leu Leu Arg Lys Arg  
                                 80                                85                                87

## (2) INFORMATION FOR SEQ ID NO:19:

10     (i) SEQUENCE CHARACTERISTICS:  
               (A) LENGTH: 86 amino acids  
               (B) TYPE: amino acid  
               (D) TOPOLOGY: linear

15     (xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

          Lys Lys Arg Asp Pro Cys Leu Arg Lys Tyr Lys Asp Phe Cys Ile  
           1                                5                                10                                15

20     His Gly Glu Cys Lys Tyr Val Lys Glu Leu Arg Ala Pro Ser Cys  
                                 20                                25                                30

          Ile Cys His Pro Gly Tyr His Gly Glu Arg Cys His Gly Leu Ser  
                                 35                                40                                45

25     Leu Pro Val Glu Asn Arg Leu Tyr Thr Tyr Asp His Thr Thr Ile  
                                 50                                55                                60

          Leu Ala Val Val Ala Val Val Leu Ser Ser Val Cys Leu Leu Val  
                                 65                                70                                75

30     Ile Val Gly Leu Leu Met Phe Arg Tyr His Arg  
                                 80                                85                                86

## (2) INFORMATION FOR SEQ ID NO:20:

35     (i) SEQUENCE CHARACTERISTICS:  
               (A) LENGTH: 13 amino acids  
               (B) TYPE: amino acid  
               (D) TOPOLOGY: linear

40     (xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

          Arg Pro Asn Ala Arg Leu Pro Pro Gly Val Phe Tyr Cys  
           1                                5                                10                                13

## (2) INFORMATION FOR SEQ ID NO:21:

50     (i) SEQUENCE CHARACTERISTICS:  
               (A) LENGTH: 25 bases  
               (B) TYPE: nucleic acid  
               (C) STRANDEDNESS: single  
               (D) TOPOLOGY: linear

55     (xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

CCTCGCTCCT TCTTCTTGCC CTTCC 25

## (2) INFORMATION FOR SEQ ID NO:22:

## (i) SEQUENCE CHARACTERISTICS:

5

- (A) LENGTH: 496 bases  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

10

AA AGA GCC GGC GAG GAG TTC CCC GAA ACT TGT TGG AAC 38  
 Arg Ala Gly Glu Glu Phe Pro Glu Thr Cys Trp Asn  
 1 5 10

15

TCC GGG CTC GCG CGG AGG CCA GGA GCT GAG CGG CGG CGG 77  
 Ser Gly Leu Ala Arg Arg Pro Gly Ala Glu Arg Arg Arg  
 15 20 25

20

CTG CCG GAC GAT GGG AGC GTG AGC AGG ACG GTG ATA ACC 116  
 Leu Pro Asp Asp Gly Ser Val Ser Arg Thr Val Ile Thr  
 30 35

25

TCT CCC CGA TCG GGT TGC GAG GGC GCC GGG CAG AGG CCA 155  
 Ser Pro Arg Ser Gly Cys Glu Gly Ala Gly Gln Arg Pro  
 40 45 50

30

GGA CGC GAG CCG CCA GCG GTG GGA CCC ATC GAC GAC TTC 194  
 Gly Arg Glu Pro Pro Ala Val Gly Pro Ile Asp Asp Phe  
 55 60

35

CCG GGG CGA CAG GAG CAG CCC CGA GAG CCA GGG CGA GCG 233  
 Pro Gly Arg Gln Glu Gln Pro Arg Glu Pro Gly Arg Ala  
 65 70 75

CCC GTT CCA GGT GGC CGG ACC GCC CGC CGC GTC CGC GCC 272  
 Pro Val Pro Gly Gly Arg Thr Ala Arg Arg Val Arg Ala  
 80 85 90

40

GCG CTC CCT GCA GGC AAC GGG AGA CGC CCC CGC GCA GCG 311  
 Ala Leu Pro Ala Gly Asn Gly Arg Arg Pro Arg Ala Ala  
 95 100

45

CGA GCG CCT CAG CGC GGC CGC TCG CTC TCC CCC TCG AGG 350  
 Arg Ala Pro Gln Arg Gly Arg Ser Leu Ser Pro Ser Arg  
 105 110 115

50

GAC AAA CTT TTC CCA AAC CCG ATC CGA GCC CTT GGA CCA 389  
 Asp Lys Leu Phe Pro Asn Pro Ile Arg Ala Leu Gly Pro  
 120 125

55

AAC TCG CCT GCG CCG AGA GCC GTC CGC GTA GAG CGC TCC 428  
 Asn Ser Pro Ala Pro Arg Ala Val Arg Val Glu Arg Ser  
 130 135 140

GTC TCC GGC GAG ATG TCC GAG CGC AAA GAA GGC AGA GGC 467  
 Val Ser Gly Glu Met Ser Glu Arg Lys Glu Gly Arg Gly  
 145 150 155

60

AAA GGG AAG GGC AAG AAG AAG GAG CGA GG 496  
 Lys Gly Lys Gly Lys Lys Lys Glu Arg  
 160 164



83

## (2) INFORMATION FOR SEQ ID NO:23:

## (i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 2490 bases  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

10

GTGGCTGCGG GGCAATTGAA AAAGAGCCGG CGAGGAGTTC CCCGAAACTT 50

15

GTTGGAATC CGGGCTCGCG CGGAGGCCAG GAGCTGAGCG GCGGCGGCTG 100

CCGGACGATG GGAGCGTGAG CAGGACGGTG ATAACCTCTC CCCGATCGGG 150

20

TTGCGAGGGC GCCGGGCAGA GGCCAGGACG CGAGCCGCCA GCGGCGGGAC 200

25

CCATCGACGA CTTCCCGGGG CGACAGGAGC AGCCCCGAGA GCCAGGGCGA 250

GCGCCCGTTC CAGGTGGCCG GACCGCCCGC CGCGTCCGCG CCGCGCTCCC 300

30

TGCAGGCAAC GGGAGACGCC CCCGCGCAGC GCGAGCGCCT CAGCGCGGCC 350

GCTCGCTCTC CCCATCGAGG GACAAACTTT TCCCAAACCC GATCCGAGCC 400

35

CTTGACCAA ACTCGCCTGC GCCGAGAGCC GTCCGCGTAG AGCGCTCCGT 450

40

CTCCGGCGAG	ATG	TCC	GAG	CGC	AAA	GAA	GGC	AGA	GGC	AAA	490
	Met	Ser	Glu	Arg	Lys	Glu	Gly	Arg	Gly	Lys	
	1				5					10	

45

GGG	AAG	GGC	AAG	AAG	AAG	GAG	CGA	GGC	TCC	GGC	AAG	AAG	529
Gly	Lys	Gly	Lys	Lys	Lys	Glu	Arg	Gly	Ser	Gly	Lys	Lys	
				15					20				

50

CCG	GAG	TCC	GCG	GCG	GGC	AGC	CAG	AGC	CCA	GCC	TTG	CCT	568
Pro	Glu	Ser	Ala	Ala	Gly	Ser	Gln	Ser	Pro	Ala	Leu	Pro	
	25					30					35		

55

CCC	CAA	TTG	AAA	GAG	ATG	AAA	AGC	CAG	GAA	TCG	GCT	GCA	607
Pro	Gln	Leu	Lys	Glu	Met	Lys	Ser	Gln	Glu	Ser	Ala	Ala	
			40					45					

60

GGT	TCC	AAA	CTA	GTC	CTT	CGG	TGT	GAA	ACC	AGT	TCT	GAA	646
Gly	Ser	Lys	Leu	Val	Leu	Arg	Cys	Glu	Thr	Ser	Ser	Glu	
	50					55					60		

TAC	TCC	TCT	CTC	AGA	TTC	AAG	TGG	TTC	AAG	AAT	GGG	AAT	685
Tyr	Ser	Ser	Leu	Arg	Phe	Lys	Trp	Phe	Lys	Asn	Gly	Asn	
			65				70					75	

84

	GAA TTG AAT CGA AAA AAC AAA CCA CAA AAT ATC AAG ATA 724
	Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile Lys Ile
	80 85
5	CAA AAA AAG CCA GGG AAG TCA GAA CTT CGC ATT AAC AAA 763
	Gln Lys Lys Pro Gly Lys Ser Glu Leu Arg Ile Asn Lys
	90 95 100
10	GCA TCA CTG GCT GAT TCT GGA GAG TAT ATG TGC AAA GTG 802
	Ala Ser Leu Ala Asp Ser Gly Glu Tyr Met Cys Lys Val
	105 110
15	ATC AGC AAA TTA GGA AAT GAC AGT GCC TCT GCC AAT ATC 841
	Ile Ser Lys Leu Gly Asn Asp Ser Ala Ser Ala Asn Ile
	115 120 125
20	ACC ATC GTG GAA TCA AAC GAG ATC ATC ACT GGT ATG CCA 880
	Thr Ile Val Glu Ser Asn Glu Ile Ile Thr Gly Met Pro
	130 135 140
25	GCC TCA ACT GAA GGA GCA TAT GTG TCT TCA GAG TCT CCC 919
	Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser Glu Ser Pro
	145 150
30	ATT AGA ATA TCA GTA TCC ACA GAA GGA GCA AAT ACT TCT 958
	Ile Arg Ile Ser Val Ser Thr Glu Gly Ala Asn Thr Ser
	155 160 165
35	TCA TCT ACA TCT ACA TCC ACC ACT GGG ACA AGC CAT CTT 997
	Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr Ser His Leu
	170 175
40	GTA AAA TGT GCG GAG AAG GAG AAA ACT TTC TGT GTG AAT 1036
	Val Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val Asn
	180 185 190
45	GGA GGG GAG TGC TTC ATG GTG AAA GAC CTT TCA AAC CCC 1075
	Gly Gly Glu Cys Phe Met Val Lys Asp Leu Ser Asn Pro
	195 200 205
50	TCG AGA TAC TTG TGC AAG TGC CCA AAT GAG TTT ACT GGT 1114
	Ser Arg Tyr Leu Cys Lys Cys Pro Asn Glu Phe Thr Gly
	210 215
55	GAT CGC TGC CAA AAC TAC GTA ATG GCC AGC TTC TAC AAG 1153
	Asp Arg Cys Gln Asn Tyr Val Met Ala Ser Phe Tyr Lys
	220 225 230
60	GCG GAG GAG CTG TAC CAG AAG AGA GTG CTG ACC ATA ACC 1192
	Ala Glu Glu Leu Tyr Gln Lys Arg Val Leu Thr Ile Thr
	235 240
65	GGC ATC TGC ATC GCC CTC CTT GTG GTC GGC ATC ATG TGT 1231
	Gly Ile Cys Ile Ala Leu Leu Val Val Gly Ile Met Cys
	245 250 255
70	GTG GTG GCC TAC TGC AAA ACC AAG AAA CAG CGG AAA AAG 1270
	Val Val Ala Tyr Cys Lys Thr Lys Lys Gln Arg Lys Lys
	260 265 270
75	CTG CAT GAC CGT CTT CGG CAG AGC CTT CGG TCT GAA CGA 1309
	Leu His Asp Arg Leu Arg Gln Ser Leu Arg Ser Glu Arg
	275 280

85

	AAC AAT ATG ATG AAC ATT GCC AAT GGG CCT CAC CAT CCT 1348
	Asn Asn Met Met Asn Ile Ala Asn Gly Pro His His Pro
	285 290 295
5	AAC CCA CCC CCC GAG AAT GTC CAG CTG GTG AAT CAA TAC 1387
	Asn Pro Pro Pro Glu Asn Val Gln Leu Val Asn Gln Tyr
	300 305
10	GTA TCT AAA AAC GTC ATC TCC AGT GAG CAT ATT GTT GAG 1426
	Val Ser Lys Asn Val Ile Ser Ser Glu His Ile Val Glu
	310 315 320
15	AGA GAA GCA GAG ACA TCC TTT TCC ACC AGT CAC TAT ACT 1465
	Arg Glu Ala Glu Thr Ser Phe Ser Thr Ser His Tyr Thr
	325 330 335
20	TCC ACA GCC CAT CAC TCC ACT ACT GTC ACC CAG ACT CCT 1504
	Ser Thr Ala His His Ser Thr Thr Val Thr Gln Thr Pro
	340 345
25	AGC CAC AGC TGG AGC AAC GGA CAC ACT GAA AGC ATC CTT 1543
	Ser His Ser Trp Ser Asn Gly His Thr Glu Ser Ile Leu
	350 355 360
30	TCC GAA AGC CAC TCT GTA ATC GTG ATG TCA TCC GTA GAA 1582
	Ser Glu Ser His Ser Val Ile Val Met Ser Ser Val Glu
	365 370
35	AAC AGT AGG CAC AGC AGC CCA ACT GGG GGC CCA AGA GGA 1621
	Asn Ser Arg His Ser Ser Pro Thr Gly Gly Pro Arg Gly
	375 380 385
40	CGT CTT AAT GGC ACA GGA GGC CCT CGT GAA TGT AAC AGC 1660
	Arg Leu Asn Gly Thr Gly Gly Pro Arg Glu Cys Asn Ser
	390 395 400
45	TTC CTC AGG CAT GCC AGA GAA ACC CCT GAT TCC TAC CGA 1699
	Phe Leu Arg His Ala Arg Glu Thr Pro Asp Ser Tyr Arg
	405 410
50	GAC TCT CCT CAT AGT GAA AGG TAT GTG TCA GCC ATG ACC 1738
	Asp Ser Pro His Ser Glu Arg Tyr Val Ser Ala Met Thr
	415 420 425
55	ACC CCG GCT CGT ATG TCA CCT GTA GAT TTC CAC ACG CCA 1777
	Thr Pro Ala Arg Met Ser Pro Val Asp Phe His Thr Pro
	430 435
60	AGC TCC CCC AAA TCG CCC CCT TCG GAA ATG TCT CCA CCC 1816
	Ser Ser Pro Lys Ser Pro Ser Glu Met Ser Pro Pro
	440 445 450
65	GTG TCC AGC ATG ACG GTG TCC AAG CCT TCC ATG GCG GTC 1855
	Val Ser Ser Met Thr Val Ser Lys Pro Ser Met Ala Val
	455 460 465
70	AGC CCC TTC ATG GAA GAA GAG AGA CCT CTA CTT CTC GTG 1894
	Ser Pro Phe Met Glu Glu Glu Arg Pro Leu Leu Leu Val
	470 475
75	ACA CCA CCA AGG CTG CGG GAG AAG AAG TTT GAC CAT CAC 1933
	Thr Pro Pro Arg Leu Arg Glu Lys Lys Phe Asp His His
	480 485 490

86

	CCT	CAG	CAG	TTC	AGC	TCC	TTC	CAC	CAC	AAC	CCC	GCG	CAT	1972
	Pro	Gln	Gln	Phe	Ser	Ser	Phe	His	His	Asn	Pro	Ala	His	
				495						500				
5	GAC	AGT	AAC	AGC	CTC	CCT	GCT	AGC	CCC	TTG	AGG	ATA	GTG	2011
	Asp	Ser	Asn	Ser	Leu	Pro	Ala	Ser	Pro	Leu	Arg	Ile	Val	
	505					510					515			
10	GAG	GAT	GAG	GAG	TAT	GAA	ACG	ACC	CAA	GAG	TAC	GAG	CCA	2050
	Glu	Asp	Glu	Glu	Tyr	Glu	Thr	Thr	Gln	Glu	Tyr	Glu	Pro	
			520					525					530	
15	GCC	CAA	GAG	CCT	GTT	AAG	AAA	CTC	GCC	AAT	AGC	CGG	CGG	2089
	Ala	Gln	Glu	Pro	Val	Lys	Lys	Leu	Ala	Asn	Ser	Arg	Arg	
					535					540				
20	GCC	AAA	AGA	ACC	AAG	CCC	AAT	GGC	CAC	ATT	GCT	AAC	AGA	2128
	Ala	Lys	Arg	Thr	Lys	Pro	Asn	Gly	His	Ile	Ala	Asn	Arg	
		545					550					555		
25	TTG	GAA	GTG	GAC	AGC	AAC	ACA	AGC	TCC	CAG	AGC	AGT	AAC	2167
	Leu	Glu	Val	Asp	Ser	Asn	Thr	Ser	Ser	Gln	Ser	Ser	Asn	
				560					565					
30	TCA	GAG	AGT	GAA	ACA	GAA	GAT	GAA	AGA	GTA	GGT	GAA	GAT	2206
	Ser	Glu	Ser	Glu	Thr	Glu	Asp	Glu	Arg	Val	Gly	Glu	Asp	
	570					575					580			
35	ACG	CCT	TTC	CTG	GGC	ATA	CAG	AAC	CCC	CTG	GCA	GCC	AGT	2245
	Thr	Pro	Phe	Leu	Gly	Ile	Gln	Asn	Pro	Leu	Ala	Ala	Ser	
			585					590					595	
40	CTT	GAG	GCA	ACA	CCT	GCC	TTC	CGC	CTG	GCT	GAC	AGC	AGG	2284
	Leu	Glu	Ala	Thr	Pro	Ala	Phe	Arg	Leu	Ala	Asp	Ser	Arg	
					600					605				
45	ACT	AAC	CCA	GCA	GGC	CGC	TTC	TCG	ACA	CAG	GAA	GAA	ATC	2323
	Thr	Asn	Pro	Ala	Gly	Arg	Phe	Ser	Thr	Gln	Glu	Glu	Ile	
		610					615					620		
50	CAG	GCC	AGG	CTG	TCT	AGT	GTA	ATT	GCT	AAC	CAA	GAC	CCT	2362
	Gln	Ala	Arg	Leu	Ser	Ser	Val	Ile	Ala	Asn	Gln	Asp	Pro	
				625					630					
55	ATT	GCT	GTA	TAAAACCTA	AATAAACACA	TAGATTCACC	TGTAAACTT	2410						
	Ile	Ala	Val											
	635		637											
60	TATTTTATAT	AATAAAGTAT	TCCACCTTAA	ATTAAACAAT	TTATTTTATT	2460								
	TTAGCAGTTC	TGCAAATAAA	AAAAAAAAAA	2490										

(2) INFORMATION FOR SEQ ID NO:24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1715 bases
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

87

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

5 GCGCCTGCCT CCAACCTGCG GGC GGGAGGT GGGTGGCTGC GGGGCAATTG 50  
 AAAAAGAGCC GGC GAGGAGT TCCCCGAAAC TTGTTGGAAC TCCGGGCTCG 100  
 10 CGCGGAGGCC AGGAGCTGAG CGGCGGCGGC TGCCGGACGA TGGGAGCGTG 150  
 AGCAGGACGG TGATAACCTC TCCCCGATCG GGTTCGAGG GCGCCGGGCA 200  
 15 GAGGCCAGGA CGCGAGCCGC CAGCGGCGGG ACCCATCGAC GACTTCCCGG 250  
 GCGGACAGGA GCAGCCCCGA GAGCCAGGGC GAGCGCCCGT TCCAGGT GC 300  
 20 CGGACCGCCC GCCGCGTCCG CGCCGCGCTC CCTGCAGGCA ACGGGAGACG 350  
 25 CCCCCGCGCA GCGCGAGCGC CTCAGCGCGG CCGCTCGCTC TCCCCATCGA 400  
 GGGACAAACT TTTCCCAAAC CCGATCCGAG CCCTTGGACC AAAC TCGCCT 450  
 30 GCGCCGAGAG CCGTCCGCGT AGAGCGCTCC GTCTCCGGCG AG ATG 495  
 Met  
 1  
 35 TCC GAG CGC AAA GAA GGC AGA GGC AAA GGG AAG GGC AAG 534  
 Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys  
 5 10  
 40 AAG AAG GAG CGA GGC TCC GGC AAG AAG CCG GAG TCC GCG 573  
 Lys Lys Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala  
 15 20 25  
 45 GCG GGC AGC CAG AGC CCA GCC TTG CCT CCC CAA TTG AAA 612  
 Ala Gly Ser Gln Ser Pro Ala Leu Pro Pro Gln Leu Lys  
 30 35 40  
 GAG ATG AAA AGC CAG GAA TCG GCT GCA GGT TCC AAA CTA 651  
 Glu Met Lys Ser Gln Glu Ser Ala Ala Gly Ser Lys Leu  
 45 50  
 50 GTC CTT CGG TGT GAA ACC AGT TCT GAA TAC TCC TCT CTC 690  
 Val Leu Arg Cys Glu Thr Ser Ser Glu Tyr Ser Ser Leu  
 55 60 65  
 55 AGA TTC AAG TGG TTC AAG AAT GGG AAT GAA TTG AAT CGA 729  
 Arg Phe Lys Trp Phe Lys Asn Gly Asn Glu Leu Asn Arg  
 70 75  
 60 AAA AAC AAA CCA CAA AAT ATC AAG ATA CAA AAA AAG CCA 768  
 Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys Lys Pro  
 80 85 90

88

GGG AAG TCA GAA CTT CGC ATT AAC AAA GCA TCA CTG GCT 807  
 Gly Lys Ser Glu Leu Arg Ile Asn Lys Ala Ser Leu Ala 105  
 95 100

5 GAT TCT GGA GAG TAT ATG TGC AAA GTG ATC AGC AAA TTA 846  
 Asp Ser Gly Glu Tyr Met Cys Lys Val Ile Ser Lys Leu 115  
 110

10 GGA AAT GAC AGT GCC TCT GCC AAT ATC ACC ATC GTG GAA 885  
 Gly Asn Asp Ser Ala Ser Ala Asn Ile Thr Ile Val Glu 130  
 120 125

15 TCA AAC GAG ATC ATC ACT GGT ATG CCA GCC TCA ACT GAA 924  
 Ser Asn Glu Ile Ile Thr Gly Met Pro Ala Ser Thr Glu 140  
 135

20 GGA GCA TAT GTG TCT TCA GAG TCT CCC ATT AGA ATA TCA 963  
 Gly Ala Tyr Val Ser Ser Glu Ser Pro Ile Arg Ile Ser 155  
 145 150

25 GTA TCC ACA GAA GGA GCA AAT ACT TCT TCA TCT ACA TCT 1002  
 Val Ser Thr Glu Gly Ala Asn Thr Ser Ser Ser Thr Ser 170  
 160 165

30 ACA TCC ACC ACT GGG ACA AGC CAT CTT GTA AAA TGT GCG 1041  
 Thr Ser Thr Thr Gly Thr Ser His Leu Val Lys Cys Ala 180  
 175

35 GAG AAG GAG AAA ACT TTC TGT GTG AAT GGA GGG GAG TGC 1080  
 Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu Cys 195  
 185 190

40 TTC ATG GTG AAA GAC CTT TCA AAC CCC TCG AGA TAC TTG 1119  
 Phe Met Val Lys Asp Leu Ser Asn Pro Ser Arg Tyr Leu 205  
 200

45 TGC AAG TGC CCA AAT GAG TTT ACT GGT GAT CGC TGC CAA 1158  
 Cys Lys Cys Pro Asn Glu Phe Thr Gly Asp Arg Cys Gln 220  
 210 215

50 AAC TAC GTA ATG GCC AGC TTC TAC AGT ACG TCC ACT CCC 1197  
 Asn Tyr Val Met Ala Ser Phe Tyr Ser Thr Ser Thr Pro 235  
 225 230

55 TTT CTG TCT CTG CCT GAA TAGGA GCATGCTCAG TTGGTGCTGC 1240  
 Phe Leu Ser Leu Pro Glu 240 241

60 TTTCTTGTTG CTGCATCTCC CCTCAGATTC CACCTAGAGC TAGATGTGTC 1290

TTACCAGATC TAATATTGAC TGCCTCTGCC TGTCGCATGA GAACATTAAC 1340

AAAAGCAATT GTATTACTTC CTCTGTTTCGC GACTAGTTGG CTCTGAGATA 1390

CTAATAGGTG TGTGAGGCTC CGGATGTTTC TGGAATTGAT ATTGAATGAT 1440

60 GTGATACAAA TTGATAGTCA ATATCAAGCA GTGAAATATG ATAATAAAGG 1490

CATTTCAAAG TCTCACTTTT ATTGATAAAA TAAAAATCAT TCTACTGAAC 1540

5 AGTCCATCTT CTTTATACAA TGACCACATC CTGAAAAGGG TGTTGCTAAG 1590  
 CTGTAACCGA TATGCACTTG AAATGATGGT AAGTTAATTT TGATTCAGAA 1640  
 10 TGTGTTATTT GTCACAAATA AACATAATAA AAGGAGTTCA GATGTTTTTC 1690  
 TTCATTAACC AAAAAAAAAA AAAAA 1715

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

20 (A) LENGTH: 2431 bases  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: N.A.  
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

25 GAGGCGCCTG CCTCCAACCT GCGGGCGGGA GGTGGGTGGC TCGGGGGCAA 50  
 30 TTGAAAAGA GCCGCGGAGG AGTTCCCCGA AACTTGTTGG AACTCCGGGC 100  
 TCGCGCGGAG GCCAGGAGCT GAGCGCGGCG GGCTGCCGGA CGATGGGAGC 150  
 35 GTGAGCAGGA CGGTGATAAC CTCTCCCCGA TCGGGTTGCG AGGGCGCCGG 200  
 GCAGAGGCCA GGACGCGAGC CGCCAGCGGC GGGACCCATC GACGACTTCC 250  
 40 CGGGGCGACA GGAGCAGCCC CGAGAGCCAG GGCGAGCGCC CGTTCCAGGT 300  
 45 GGCCGGACCG CCCGCCGCGT CCGCGCCGCG CTCCCTGCAG GCAACGGGAG 350  
 ACGCCCCCGC GCAGCGCGAG CGCCTCAGCG CGGCCGCTCG CTCTCCCCAT 400  
 50 CGAGGGACAA ACTTTTCCCA AACCCGATCC GAGCCCTTGG ACCAAACTCG 450  
 55 CCTGCGCCGA GAGCCGTCCG CGTAGAGCGC TCCGTCTCCG GCGAG AT 497  
 Met  
 1  
 60 G TCC GAG CGC AAA GAA GGC AGA GGC AAA GGG AAG GGC AAG 537  
 Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys  
 5 10  
 AAG AAG GAG CGA GGC TCC GGC AAG AAG CCG GAG TCC GCG 576  
 Lys Lys Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala  
 15 20 25

## 90

5	GCG GGC AGC CAG AGC CCA GCC TTG CCT CCC CAA TTG AAA 615	
	Ala Gly Ser Gln Ser Pro Ala Leu Pro Pro Gln Leu Lys 40	
10	GAG ATG AAA AGC CAG GAA TCG GCT GCA GGT TCC AAA CTA 654	
	Glu Met Lys Ser Gln Glu Ser Ala Ala Gly Ser Lys Leu 50	
15	GTC CTT CGG TGT GAA ACC AGT TCT GAA TAC TCC TCT CTC 693	
	Val Leu Arg Cys Glu Thr Ser Ser Glu Tyr Ser Ser Leu 65	
20	AGA TTC AAG TGG TTC AAG AAT GGG AAT GAA TTG AAT CGA 732	
	Arg Phe Lys Trp Phe Lys Asn Gly Asn Glu Leu Asn Arg 75	
25	AAA AAC AAA CCA CAA AAT ATC AAG ATA CAA AAA AAG CCA 771	
	Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys Lys Pro 90	
30	GGG AAG TCA GAA CTT CGC ATT AAC AAA GCA TCA CTG GCT 810	
	Gly Lys Ser Glu Leu Arg Ile Asn Lys Ala Ser Leu Ala 105	
35	GAT TCT GGA GAG TAT ATG TGC AAA GTG ATC AGC AAA TTA 849	
	Asp Ser Gly Glu Tyr Met Cys Lys Val Ile Ser Lys Leu 115	
40	GGA AAT GAC AGT GCC TCT GCC AAT ATC ACC ATC GTG GAA 888	
	Gly Asn Asp Ser Ala Ser Ala Asn Ile Thr Ile Val Glu 130	
45	TCA AAC GAG ATC ATC ACT GGT ATG CCA GCC TCA ACT GAA 927	
	Ser Asn Glu Ile Ile Thr Gly Met Pro Ala Ser Thr Glu 140	
50	GGA GCA TAT GTG TCT TCA GAG TCT CCC ATT AGA ATA TCA 966	
	Gly Ala Tyr Val Ser Ser Glu Ser Pro Ile Arg Ile Ser 155	
55	GTA TCC ACA GAA GGA GCA AAT ACT TCT TCA TCT ACA TCT 1005	
	Val Ser Thr Glu Gly Ala Asn Thr Ser Ser Ser Thr Ser 170	
60	ACA TCC ACC ACT GGG ACA AGC CAT CTT GTA AAA TGT GCG 1044	
	Thr Ser Thr Thr Gly Thr Ser His Leu Val Lys Cys Ala 180	
65	GAG AAG GAG AAA ACT TTC TGT GTG AAT GGA GGG GAG TGC 1083	
	Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu Cys 195	
70	TTC ATG GTG AAA GAC CTT TCA AAC CCC TCG AGA TAC TTG 1122	
	Phe Met Val Lys Asp Leu Ser Asn Pro Ser Arg Tyr Leu 205	
75	TGC AAG TGC CCA AAT GAG TTT ACT GGT GAT CGC TGC CAA 1161	
	Cys Lys Cys Pro Asn Glu Phe Thr Gly Asp Arg Cys Gln 220	
80	AAC TAC GTA ATG GCC AGC TTC TAC AAG GCG GAG GAG CTG 1200	
	Asn Tyr Val Met Ala Ser Phe Tyr Lys Ala Glu Glu Leu 235	



5 TAC CAG AAG AGA GTG CTG ACC ATA ACC GGC ATC TGC ATC 1239  
 Tyr Gln Lys Arg Val Leu Thr Ile Thr Gly Ile Cys Ile  
 240 245

10 GCC CTC CTT GTG GTC GGC ATC ATG TGT GTG GTG GCC TAC 1278  
 Ala Leu Leu Val Val Gly Ile Met Cys Val Val Ala Tyr  
 250 255 260

15 TGC AAA ACC AAG AAA CAG CGG AAA AAG CTG CAT GAC CGT 1317  
 Cys Lys Thr Lys Lys Gln Arg Lys Lys Leu His Asp Arg  
 265 270

20 CTT CGG CAG AGC CTT CGG TCT GAA CGA AAC AAT ATG ATG 1356  
 Leu Arg Gln Ser Leu Arg Ser Glu Arg Asn Asn Met Met  
 275 280 285

25 AAC ATT GCC AAT GGG CCT CAC CAT CCT AAC CCA CCC CCC 1395  
 Asn Ile Ala Asn Gly Pro His His Pro Asn Pro Pro Pro  
 290 295 300

30 GAG AAT GTC CAG CTG GTG AAT CAA TAC GTA TCT AAA AAC 1434  
 Glu Asn Val Gln Leu Val Asn Gln Tyr Val Ser Lys Asn  
 305 310

35 GTC ATC TCC AGT GAG CAT ATT GTT GAG AGA GAA GCA GAG 1473  
 Val Ile Ser Ser Glu His Ile Val Glu Arg Glu Ala Glu  
 315 320 325

40 ACA TCC TTT TCC ACC AGT CAC TAT ACT TCC ACA GCC CAT 1512  
 Thr Ser Phe Ser Thr Ser His Tyr Thr Ser Thr Ala His  
 330 335

45 CAC TCC ACT ACT GTC ACC CAG ACT CCT AGC CAC AGC TGG 1551  
 His Ser Thr Thr Val Thr Gln Thr Pro Ser His Ser Trp  
 340 345 350

50 AGC AAC GGA CAC ACT GAA AGC ATC CTT TCC GAA AGC CAC 1590  
 Ser Asn Gly His Thr Glu Ser Ile Leu Ser Glu Ser His  
 355 360 365

55 TCT GTA ATC GTG ATG TCA TCC GTA GAA AAC AGT AGG CAC 1629  
 Ser Val Ile Val Met Ser Ser Val Glu Asn Ser Arg His  
 370 375

60 AGC AGC CCA ACT GGG GGC CCA AGA GGA CGT CTT AAT GGC 1668  
 Ser Ser Pro Thr Gly Gly Pro Arg Gly Arg Leu Asn Gly  
 380 385 390

65 ACA GGA GGC CCT CGT GAA TGT AAC AGC TTC CTC AGG CAT 1707  
 Thr Gly Gly Pro Arg Glu Cys Asn Ser Phe Leu Arg His  
 395 400

70 GCC AGA GAA ACC CCT GAT TCC TAC CGA GAC TCT CCT CAT 1746  
 Ala Arg Glu Thr Pro Asp Ser Tyr Arg Asp Ser Pro His  
 405 410 415

75 AGT GAA AGG TAAAA CCGAAGGCAA AGCTACTGCA GAGGAGAAAC 1790  
 Ser Glu Arg  
 420

80 TCAGTCAGAG AATCCCTGTG AGCACCTGCG GTCTCACCTC AGGAAATCTA 1840

92

CTCTAATCAG AATAAGGGGC GGCAGTTACC TGTTCCTAGGA GTGCTCCTAG 1890  
 TTGATGAAGT CATCTCTTTG TTTGACGGAA CTTATTTCTT CTGAGCTTCT 1940  
 5 CTGTCGTCC CAGTGACTGA CAGGCAACAG ACTCTTAAAG AGCTGGGATG 1990  
 CTTTGATGCG GAAGGTGCAG CACATGGAGT TTCCAGCTCT GGCCATGGGC 2040  
 10 TCAGACCCAC TCGGGGTCTC AGTGTCTCA GTTGTAACAT TAGAGAGATG 2090  
 GCATCAATGC TTGATAAGGA CCCTTCTATA ATTCCAATTG CCAGTTATCC 2140  
 15 AAACCTCTGAT TCGGTGGTCG AGCTGGCCTC GTGTTCTTAT CTGCTAACCC 2190  
 20 TGTCTTACCT TCCAGCCTCA GTTAAGTCAA ATCAAGGGCT ATGTCATTGC 2240  
 TGAATGTCAT GGGGGGCAAC TGCTTGCCCT CCACCCTATA GTATCTATTT 2290  
 25 TATGAAATTC CAAGAAGGGA TGAATAAATA AATCTCTTGG ATGCTGCGTC 2340  
 30 TGGCAGTCTT CACGGGTGGT TTTCAAAGCA GAAAAAAAAA AAAAAAAAAA 2390  
 AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA A 2431  
 35

## (2) INFORMATION FOR SEQ ID NO:26:

40 (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 625 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

Met	Ser	Glu	Arg	Lys	Glu	Gly	Arg	Gly	Lys	Gly	Lys	Gly	Lys	Lys	1	5	10	15
Lys	Glu	Arg	Gly	Ser	Gly	Lys	Lys	Pro	Glu	Ser	Ala	Ala	Gly	Ser	20	25	30	
Gln	Ser	Pro	Ala	Leu	Pro	Pro	Arg	Leu	Lys	Glu	Met	Lys	Ser	Gln	35	40	45	
Glu	Ser	Ala	Ala	Gly	Ser	Lys	Leu	Val	Leu	Arg	Cys	Glu	Thr	Ser	50	55	60	
Ser	Glu	Tyr	Ser	Ser	Leu	Arg	Phe	Lys	Trp	Phe	Lys	Asn	Gly	Asn	65	70	75	
Glu	Leu	Asn	Arg	Lys	Asn	Lys	Pro	Gln	Asn	Ile	Lys	Ile	Gln	Lys	80	85	90	

	Lys	Pro	Gly	Lys	Ser	Glu	Leu	Arg	Ile	Asn	Lys	Ala	Ser	Leu	Ala	
					95					100					105	
5	Asp	Ser	Gly	Glu	Tyr	Met	Cys	Lys	Val	Ile	Ser	Lys	Leu	Gly	Asn	
					110					115					120	
	Asp	Ser	Ala	Ser	Ala	Asn	Ile	Thr	Ile	Val	Glu	Ser	Asn	Glu	Ile	
					125					130					135	
10	Ile	Thr	Gly	Met	Pro	Ala	Ser	Thr	Glu	Gly	Ala	Tyr	Val	Ser	Ser	
					140					145					150	
	Glu	Ser	Pro	Ile	Arg	Ile	Ser	Val	Ser	Thr	Glu	Gly	Ala	Asn	Thr	
15					155					160					165	
	Ser	Ser	Ser	Thr	Ser	Thr	Ser	Thr	Thr	Gly	Thr	Ser	His	Leu	Val	
					170					175					180	
20	Lys	Cys	Ala	Glu	Lys	Glu	Lys	Thr	Phe	Cys	Val	Asn	Gly	Gly	Glu	
					185					190					195	
	Cys	Phe	Met	Val	Lys	Asp	Leu	Ser	Asn	Pro	Ser	Arg	Tyr	Leu	Cys	
					200					205					210	
25	Lys	Cys	Gln	Pro	Gly	Phe	Thr	Gly	Ala	Arg	Cys	Thr	Glu	Asn	Val	
					215					220					225	
	Pro	Met	Lys	Val	Gln	Asn	Gln	Glu	Lys	Ala	Glu	Glu	Leu	Tyr	Gln	
30					230					235					240	
	Lys	Arg	Val	Leu	Thr	Ile	Thr	Gly	Ile	Cys	Ile	Ala	Leu	Leu	Val	
					245					250					255	
35	Val	Gly	Ile	Met	Cys	Val	Val	Ala	Tyr	Cys	Lys	Thr	Lys	Lys	Gln	
					260					265					270	
	Arg	Lys	Lys	Leu	His	Asp	Arg	Leu	Arg	Gln	Ser	Leu	Arg	Ser	Glu	
					275					280					285	
40	Arg	Asn	Asn	Met	Met	Asn	Ile	Ala	Asn	Gly	Pro	His	His	Pro	Asn	
					290					295					300	
	Pro	Pro	Pro	Glu	Asn	Val	Gln	Leu	Val	Asn	Gln	Tyr	Val	Ser	Lys	
45					305					310					315	
	Asn	Val	Ile	Ser	Ser	Glu	His	Ile	Val	Glu	Arg	Glu	Ala	Glu	Thr	
					320					325					330	
50	Ser	Phe	Ser	Thr	Ser	His	Tyr	Thr	Ser	Thr	Ala	His	His	Ser	Thr	
					335					340					345	
	Thr	Val	Thr	Gln	Thr	Pro	Ser	His	Ser	Trp	Ser	Asn	Gly	His	Thr	
					350					355					360	
55	Glu	Ser	Ile	Leu	Ser	Glu	Ser	His	Ser	Val	Ile	Val	Met	Ser	Ser	
					365					370					375	
	Val	Glu	Asn	Ser	Arg	His	Ser	Ser	Pro	Thr	Gly	Gly	Pro	Arg	Gly	
60					380					385					390	
	Arg	Leu	Asn	Gly	Thr	Gly	Gly	Pro	Arg	Glu	Cys	Asn	Ser	Phe	Leu	
					395					400					405	

94

	Arg	His	Ala	Arg	Glu	Thr	Pro	Asp	Ser	Tyr	Arg	Asp	Ser	Pro	His
					410					415					420
5	Ser	Glu	Arg	Tyr	Val	Ser	Ala	Met	Thr	Thr	Pro	Ala	Arg	Met	Ser
					425					430					435
	Pro	Val	Asp	Phe	His	Thr	Pro	Ser	Ser	Pro	Lys	Ser	Pro	Pro	Ser
					440					445					450
10	Glu	Met	Ser	Pro	Pro	Val	Ser	Ser	Met	Thr	Val	Ser	Met	Pro	Ser
					455					460					465
	Met	Ala	Val	Ser	Pro	Phe	Met	Glu	Glu	Glu	Arg	Pro	Leu	Leu	Leu
					470					475					480
15	Val	Thr	Pro	Pro	Arg	Leu	Arg	Glu	Lys	Lys	Phe	Asp	His	His	Pro
					485					490					495
	Gln	Gln	Phe	Ser	Ser	Phe	His	His	Asn	Pro	Ala	His	Asp	Ser	Asn
20					500					505					510
	Ser	Leu	Pro	Ala	Ser	Pro	Leu	Arg	Ile	Val	Glu	Asp	Glu	Glu	Tyr
					515					520					525
25	Glu	Thr	Thr	Gln	Glu	Tyr	Glu	Pro	Ala	Gln	Glu	Pro	Val	Lys	Lys
					530					535					540
	Leu	Ala	Asn	Ser	Arg	Arg	Ala	Lys	Arg	Thr	Lys	Pro	Asn	Gly	His
					545					550					555
30	Ile	Ala	Asn	Arg	Leu	Glu	Val	Asp	Ser	Asn	Thr	Ser	Ser	Gln	Ser
					560					565					570
	Ser	Asn	Ser	Glu	Ser	Glu	Thr	Glu	Asp	Glu	Arg	Val	Gly	Glu	Asp
35					575					580					585
	Thr	Pro	Phe	Leu	Gly	Ile	Gln	Asn	Pro	Leu	Ala	Ala	Ser	Leu	Glu
					590					595					600
40	Ala	Thr	Pro	Ala	Phe	Arg	Leu	Ala	Asp	Ser	Arg	Thr	Asn	Pro	Ala
					605					610					615
	Gly	Arg	Phe	Ser	Thr	Gln	Glu	Glu	Ile	Gln					
					620					625					

45

(2) INFORMATION FOR SEQ ID NO:27:

(i) SEQUENCE CHARACTERISTICS:

50 (A) LENGTH: 645 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27:

55	Met	Ser	Glu	Arg	Lys	Glu	Gly	Arg	Gly	Lys	Gly	Lys	Gly	Lys	Lys
	1				5					10					15
	Lys	Glu	Arg	Gly	Ser	Gly	Lys	Lys	Pro	Glu	Ser	Ala	Ala	Gly	Ser
					20					25					30
60	Gln	Ser	Pro	Ala	Leu	Pro	Pro	Gln	Leu	Lys	Glu	Met	Lys	Ser	Gln
					35					40					45

95

	Glu Ser Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr Ser	50	55	60
5	Ser Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys Asn Gly Asn	65	70	75
	Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys	80	85	90
10	Lys Pro Gly Lys Ser Glu Leu Arg Ile Asn Lys Ala Ser Leu Ala	95	100	105
	Asp Ser Gly Glu Tyr Met Cys Lys Val Ile Ser Lys Leu Gly Asn	110	115	120
15	Asp Ser Ala Ser Ala Asn Ile Thr Ile Val Glu Ser Asn Glu Ile	125	130	135
	Ile Thr Gly Met Pro Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser	140	145	150
20	Glu Ser Pro Ile Arg Ile Ser Val Ser Thr Glu Gly Ala Asn Thr	155	160	165
	Ser Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr Ser His Leu Val	170	175	180
	Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu	185	190	195
30	Cys Phe Met Val Lys Asp Leu Ser Asn Pro Ser Arg Tyr Leu Cys	200	205	210
	Lys Cys Pro Asn Glu Phe Thr Gly Asp Arg Cys Gln Asn Tyr Val	215	220	225
35	Met Ala Ser Phe Tyr Lys His Leu Gly Ile Glu Phe Met Glu Ala	230	235	240
	Glu Glu Leu Tyr Gln Lys Arg Val Leu Thr Ile Thr Gly Ile Cys	245	250	255
	Ile Ala Leu Leu Val Val Gly Ile Met Cys Val Val Ala Tyr Cys	260	265	270
45	Lys Thr Lys Lys Gln Arg Lys Lys Leu His Asp Arg Leu Arg Gln	275	280	285
	Ser Leu Arg Ser Glu Arg Asn Asn Met Met Asn Ile Ala Asn Gly	290	295	300
	Pro His His Pro Asn Pro Pro Pro Glu Asn Val Gln Leu Val Asn	305	310	315
55	Gln Tyr Val Ser Lys Asn Val Ile Ser Ser Glu His Ile Val Glu	320	325	330
	Arg Glu Ala Glu Thr Ser Phe Ser Thr Ser His Tyr Thr Ser Thr	335	340	345
60	Ala His His Ser Thr Thr Val Thr Gln Thr Pro Ser His Ser Trp	350	355	360

96

	Ser	Asn	Gly	His	Thr	Glu	Ser	Ile	Leu	Ser	Glu	Ser	His	Ser	Val
					365					370					375
5	Ile	Val	Met	Ser	Ser	Val	Glu	Asn	Ser	Arg	His	Ser	Ser	Pro	Thr
					380					385					390
	Gly	Gly	Pro	Arg	Gly	Arg	Leu	Asn	Gly	Thr	Gly	Gly	Pro	Arg	Glu
					395					400					405
10	Cys	Asn	Ser	Phe	Leu	Arg	His	Ala	Arg	Glu	Thr	Pro	Asp	Ser	Tyr
					410					415					420
	Arg	Asp	Ser	Pro	His	Ser	Glu	Arg	Tyr	Val	Ser	Ala	Met	Thr	Thr
					425					430					435
15	Pro	Ala	Arg	Met	Ser	Pro	Val	Asp	Phe	His	Thr	Pro	Ser	Ser	Pro
					440					445					450
20	Lys	Ser	Pro	Pro	Ser	Glu	Met	Ser	Pro	Pro	Val	Ser	Ser	Met	Thr
					455					460					465
	Val	Ser	Met	Pro	Ser	Met	Ala	Val	Ser	Pro	Phe	Met	Glu	Glu	Glu
					470					475					480
25	Arg	Pro	Leu	Leu	Leu	Val	Thr	Pro	Pro	Arg	Leu	Arg	Glu	Lys	Lys
					485					490					495
	Phe	Asp	His	His	Pro	Gln	Gln	Phe	Ser	Ser	Phe	His	His	Asn	Pro
					500					505					510
30	Ala	His	Asp	Ser	Asn	Ser	Leu	Pro	Ala	Ser	Pro	Leu	Arg	Ile	Val
					515					520					525
35	Glu	Asp	Glu	Glu	Tyr	Glu	Thr	Thr	Gln	Glu	Tyr	Glu	Pro	Ala	Gln
					530					535					540
	Glu	Pro	Val	Lys	Lys	Leu	Ala	Asn	Ser	Arg	Arg	Ala	Lys	Arg	Thr
					545					550					555
40	Lys	Pro	Asn	Gly	His	Ile	Ala	Asn	Arg	Leu	Glu	Val	Asp	Ser	Asn
					560					565					570
	Thr	Ser	Ser	Gln	Ser	Ser	Asn	Ser	Glu	Ser	Glu	Thr	Glu	Asp	Glu
					575					580					585
45	Arg	Val	Gly	Glu	Asp	Thr	Pro	Phe	Leu	Gly	Ile	Gln	Asn	Pro	Leu
					590					595					600
	Ala	Ala	Ser	Leu	Glu	Ala	Thr	Pro	Ala	Phe	Arg	Leu	Ala	Asp	Ser
					605					610					615
50	Arg	Thr	Asn	Pro	Ala	Gly	Arg	Phe	Ser	Thr	Gln	Glu	Glu	Ile	Gln
					620					625					630
55	Ala	Arg	Leu	Ser	Ser	Val	Ile	Ala	Asn	Gln	Asp	Pro	Ile	Ala	Val
					635					640					645

(2) INFORMATION FOR SEQ ID NO:28:

60

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 637 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:28:

5	Met Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys Lys	1	5	10	15
	Lys Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala Ala Gly Ser	20	25	30	
10	Gln Ser Pro Ala Leu Pro Pro Gln Leu Lys Glu Met Lys Ser Gln	35	40	45	
	Glu Ser Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr Ser	50	55	60	
15	Ser Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys Asn Gly Asn	65	70	75	
	Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys	80	85	90	
20	Lys Pro Gly Lys Ser Glu Leu Arg Ile Asn Lys Ala Ser Leu Ala	95	100	105	
	Asp Ser Gly Glu Tyr Met Cys Lys Val Ile Ser Lys Leu Gly Asn	110	115	120	
25	Asp Ser Ala Ser Ala Asn Ile Thr Ile Val Glu Ser Asn Glu Ile	125	130	135	
30	Ile Thr Gly Met Pro Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser	140	145	150	
	Glu Ser Pro Ile Arg Ile Ser Val Ser Thr Glu Gly Ala Asn Thr	155	160	165	
35	Ser Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr Ser His Leu Val	170	175	180	
	Lys Cys Ala Glu Lys Glu Lys Thr Phe Cys Val Asn Gly Gly Glu	185	190	195	
40	Cys Phe Met Val Lys Asp Leu Ser Asn Pro Ser Arg Tyr Leu Cys	200	205	210	
45	Lys Cys Pro Asn Glu Phe Thr Gly Asp Arg Cys Gln Asn Tyr Val	215	220	225	
	Met Ala Ser Phe Tyr Lys Ala Glu Glu Leu Tyr Gln Lys Arg Val	230	235	240	
50	Leu Thr Ile Thr Gly Ile Cys Ile Ala Leu Leu Val Val Gly Ile	245	250	255	
	Met Cys Val Val Ala Tyr Cys Lys Thr Lys Lys Gln Arg Lys Lys	260	265	270	
55	Leu His Asp Arg Leu Arg Gln Ser Leu Arg Ser Glu Arg Asn Asn	275	280	285	
60	Met Met Asn Ile Ala Asn Gly Pro His His Pro Asn Pro Pro Pro	290	295	300	

	Glu	Asn	Val	Gln	Leu	Val	Asn	Gln	Tyr	Val	Ser	Lys	Asn	Val	Ile
					305					310					315
5	Ser	Ser	Glu	His	Ile	Val	Glu	Arg	Glu	Ala	Glu	Thr	Ser	Phe	Ser
					320					325					330
	Thr	Ser	His	Tyr	Thr	Ser	Thr	Ala	His	His	Ser	Thr	Thr	Val	Thr
					335					340					345
10	Gln	Thr	Pro	Ser	His	Ser	Trp	Ser	Asn	Gly	His	Thr	Glu	Ser	Ile
					350					355					360
	Leu	Ser	Glu	Ser	His	Ser	Val	Ile	Val	Met	Ser	Ser	Val	Glu	Asn
					365					370					375
15	Ser	Arg	His	Ser	Ser	Pro	Thr	Gly	Gly	Pro	Arg	Gly	Arg	Leu	Asn
					380					385					390
20	Gly	Thr	Gly	Gly	Pro	Arg	Glu	Cys	Asn	Ser	Phe	Leu	Arg	His	Ala
					395					400					405
	Arg	Glu	Thr	Pro	Asp	Ser	Tyr	Arg	Asp	Ser	Pro	His	Ser	Glu	Arg
					410					415					420
25	Tyr	Val	Ser	Ala	Met	Thr	Thr	Pro	Ala	Arg	Met	Ser	Pro	Val	Asp
					425					430					435
	Phe	His	Thr	Pro	Ser	Ser	Pro	Lys	Ser	Pro	Pro	Ser	Glu	Met	Ser
					440					445					450
30	Pro	Pro	Val	Ser	Ser	Met	Thr	Val	Ser	Lys	Pro	Ser	Met	Ala	Val
					455					460					465
35	Ser	Pro	Phe	Met	Glu	Glu	Glu	Arg	Pro	Leu	Leu	Leu	Val	Thr	Pro
					470					475					480
	Pro	Arg	Leu	Arg	Glu	Lys	Lys	Phe	Asp	His	His	Pro	Gln	Gln	Phe
					485					490					495
40	Ser	Ser	Phe	His	His	Asn	Pro	Ala	His	Asp	Ser	Asn	Ser	Leu	Pro
					500					505					510
	Ala	Ser	Pro	Leu	Arg	Ile	Val	Glu	Asp	Glu	Glu	Tyr	Glu	Thr	Thr
					515					520					525
45	Gln	Glu	Tyr	Glu	Pro	Ala	Gln	Glu	Pro	Val	Lys	Lys	Leu	Ala	Asn
					530					535					540
	Ser	Arg	Arg	Ala	Lys	Arg	Thr	Lys	Pro	Asn	Gly	His	Ile	Ala	Asn
					545					550					555
50	Arg	Leu	Glu	Val	Asp	Ser	Asn	Thr	Ser	Ser	Gln	Ser	Ser	Asn	Ser
					560					565					570
55	Glu	Ser	Glu	Thr	Glu	Asp	Glu	Arg	Val	Gly	Glu	Asp	Thr	Pro	Phe
					575					580					585
	Leu	Gly	Ile	Gln	Asn	Pro	Leu	Ala	Ala	Ser	Leu	Glu	Ala	Thr	Pro
					590					595					600
60	Ala	Phe	Arg	Leu	Ala	Asp	Ser	Arg	Thr	Asn	Pro	Ala	Gly	Arg	Phe
					605					610					615



Ser Thr Gln Glu Glu Ile Gln Ala Arg Leu Ser Ser Val Ile Ala  
620 625 630

5 Asn Gln Asp Pro Ile Ala Val  
635 637

(2) INFORMATION FOR SEQ ID NO:29:

10 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 420 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

15 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:29:

1	Met	Ser	Glu	Arg	Lys	Glu	Gly	Arg	Gly	Lys	Gly	Lys	Gly	Lys	Lys
20	Lys	Glu	Arg	Gly	Ser	Gly	Lys	Lys	Pro	Glu	Ser	Ala	Ala	Gly	Ser
30	Gln	Ser	Pro	Ala	Leu	Pro	Pro	Gln	Leu	Lys	Glu	Met	Lys	Ser	Gln
40	Glu	Ser	Ala	Ala	Gly	Ser	Lys	Leu	Val	Leu	Arg	Cys	Glu	Thr	Ser
50	Ser	Glu	Tyr	Ser	Ser	Leu	Arg	Phe	Lys	Trp	Phe	Lys	Asn	Gly	Asn
60	Glu	Leu	Asn	Arg	Lys	Asn	Lys	Pro	Gln	Asn	Ile	Lys	Ile	Gln	Lys
70	Lys	Pro	Gly	Lys	Ser	Glu	Leu	Arg	Ile	Asn	Lys	Ala	Ser	Leu	Ala
80	Asp	Ser	Gly	Glu	Tyr	Met	Cys	Lys	Val	Ile	Ser	Lys	Leu	Gly	Asn
90	Asp	Ser	Ala	Ser	Ala	Asn	Ile	Thr	Ile	Val	Glu	Ser	Asn	Glu	Ile
100	Ile	Thr	Gly	Met	Pro	Ala	Ser	Thr	Glu	Gly	Ala	Tyr	Val	Ser	Ser
110	Glu	Ser	Pro	Ile	Arg	Ile	Ser	Val	Ser	Thr	Glu	Gly	Ala	Asn	Thr
120	Ser	Ser	Ser	Thr	Ser	Thr	Ser	Thr	Thr	Gly	Thr	Ser	His	Leu	Val
130	Lys	Cys	Ala	Glu	Lys	Glu	Lys	Thr	Phe	Cys	Val	Asn	Gly	Gly	Glu
140	Cys	Phe	Met	Val	Lys	Asp	Leu	Ser	Asn	Pro	Ser	Arg	Tyr	Leu	Cys
150	Lys	Cys	Pro	Asn	Glu	Phe	Thr	Gly	Asp	Arg	Cys	Gln	Asn	Tyr	Val
160	Met	Ala	Ser	Phe	Tyr	Lys	Ala	Glu	Glu	Leu	Tyr	Gln	Lys	Arg	Val

100

	Leu Thr Ile Thr Gly Ile Cys Ile Ala Leu Leu Val Val Gly Ile	245	250	255
5	Met Cys Val Val Ala Tyr Cys Lys Thr Lys Lys Gln Arg Lys Lys	260	265	270
	Leu His Asp Arg Leu Arg Gln Ser Leu Arg Ser Glu Arg Asn Asn	275	280	285
10	Met Met Asn Ile Ala Asn Gly Pro His His Pro Asn Pro Pro Pro	290	295	300
	Glu Asn Val Gln Leu Val Asn Gln Tyr Val Ser Lys Asn Val Ile	305	310	315
15	Ser Ser Glu His Ile Val Glu Arg Glu Ala Glu Thr Ser Phe Ser	320	325	330
20	Thr Ser His Tyr Thr Ser Thr Ala His His Ser Thr Thr Val Thr	335	340	345
	Gln Thr Pro Ser His Ser Trp Ser Asn Gly His Thr Glu Ser Ile	350	355	360
25	Leu Ser Glu Ser His Ser Val Ile Val Met Ser Ser Val Glu Asn	365	370	375
	Ser Arg His Ser Ser Pro Thr Gly Gly Pro Arg Gly Arg Leu Asn	380	385	390
30	Gly Thr Gly Gly Pro Arg Glu Cys Asn Ser Phe Leu Arg His Ala	395	400	405
35	Arg Glu Thr Pro Asp Ser Tyr Arg Asp Ser Pro His Ser Glu Arg	410	415	420

## (2) INFORMATION FOR SEQ ID NO:30:

40 (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 241 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:30:

	Met Ser Glu Arg Lys Glu Gly Arg Gly Lys Gly Lys Gly Lys Lys	1	5	10	15
50	Lys Glu Arg Gly Ser Gly Lys Lys Pro Glu Ser Ala Ala Gly Ser	20	25	30	35
	Gln Ser Pro Ala Leu Pro Pro Gln Leu Lys Glu Met Lys Ser Gln	35	40	45	50
55	Glu Ser Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr Ser	50	55	60	65
60	Ser Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys Asn Gly Asn	65	70	75	80
	Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn Ile Lys Ile Gln Lys	80	85	90	95

[illegible]

## WE CLAIM:

1. A composition comprising isolated heregulin polypeptide.
- 5 2. The composition of claim 1 wherein the heregulin is antigenically active.
3. The composition of claim 1 wherein the heregulin is biologically active.
4. The composition of claim 3 wherein the heregulin is HRG-GFD.
- 10 5. The composition of claim 1 wherein the heregulin is heregulin  
- $\alpha$ , - $\beta$ 1, - $\beta$ 2, or - $\beta$ 3.
6. The composition of claim 3 wherein the heregulin is human heregulin- $\alpha$ -GFD.
- 15 7. The composition of claim 3 wherein the heregulin is human heregulin- $\beta$ 1-GFD,  
heregulin- $\beta$ 2-GFD or heregulin- $\beta$ 3-GFD .
8. The composition of claim 1 further comprising pharmaceutically acceptable carrier.
- 20 9. The composition of claim 8 wherein the heregulin is a heregulin GFD.
10. The composition of claim 9 further comprising an immune adjuvant.
- 25 11. The composition of claim 10 wherein the heregulin GFD comprises an immunogenic,  
non-heregulin polypeptide.
12. The composition of claim 1 wherein the heregulin is NTD-GFD.
- 30 13. The composition of claim 1 wherein the heregulin is NTD-GFD-transmembrane  
polypeptide.
14. The composition of claim 1 wherein the heregulin is HRG-GFD.
- 35 15. The composition of claim 1 wherein the heregulin comprises a cytoplasmic domain.
16. The composition of claim 1 wherein the heregulin is NTD-GFD and it has an amino  
acid sequence which is at least 85% homologous with the native heregulin- $\alpha$ , - $\beta$ 1,  
- $\beta$ 2, - $\beta$ 3 NTD-GFD sequence.

17. The composition of claim 1 wherein the heregulin polypeptide comprises an enzyme.
18. The composition of claim 16 wherein the heregulin is HRG- $\alpha$ .
- 5 19. The composition of claim 18 wherein the heregulin- $\alpha$  has an amino acid substituted, deleted or inserted adjacent to any one of residues 1-23, 107-108, 121-123, 128-130 and 163-247 (Fig. 15).
- 10 20. The composition of claim 16 wherein the heregulin is HRG- $\beta_1$ .
21. The composition of claim 20 wherein the heregulin  $\beta_1$  has an amino acid substituted, deleted or inserted adjacent to residues 1-23, 107-108, 121-123, 128-130 and 163-252 (Fig. 15).
- 15 22. The composition of claim 16 wherein the heregulin is HRG- $\beta_2$ .
23. The composition of claim 22 wherein the heregulin  $\beta_2$  has an amino acid substituted, deleted or inserted adjacent to any one of residues 1-23, 107-108, 121-123, 128-130 and 163-244 (Fig. 15).
- 20 24. The composition of claim 16 wherein the heregulin is HRG- $\beta_3$ .
- 25 25. The composition of claim 24 wherein the heregulin  $\beta_3$  has an amino acid substituted, deleted or inserted adjacent to any one of residues 1-23, 107-108, 121-123, 128-130 and 163-241 (Fig. 15).
26. An isolated antibody that is capable of binding a heregulin polypeptide.
- 30 27. The isolated antibody of claim 26 that is capable of binding specifically to a heregulin- $\alpha$ , heregulin- $\beta_1$ , heregulin- $\beta_2$ , or heregulin- $\beta_3$ .
28. Isolated heregulin encoding nucleic acid.
- 35 29. The nucleic acid of claim 28 which encodes heregulin- $\alpha$ , heregulin- $\beta_1$ , heregulin- $\beta_2$ , or heregulin- $\beta_3$  polypeptide.
30. The nucleic acid of claim 28 that encodes a heregulin-GFD.

31. An expression vector comprising the nucleic acid of claim 28.
32. The expression vector of claim 31 wherein the nucleic acid encodes a heregulin-GFD.
- 5 33. A host cell transformed with a vector of claim 31.
34. A method comprising culturing the host cell of claim 33 to express the heregulin and recovering the heregulin from the host cell.
- 10 35. The method of claim 34 wherein the heregulin is heregulin- $\alpha$ , heregulin- $\beta$ 1, heregulin  $\beta$ 2, or heregulin- $\beta$ 3.
36. The method of claim 34 wherein the heregulin is heregulin-NTD-GFD.
- 15 37. The method of claim 34 wherein the heregulin is heregulin-GFD.
38. A method of determining the presence of a heregulin nucleic acid, comprising contacting the nucleic acid of claim 28 with a test sample nucleic acid and determining whether hybridization has occurred.
- 20 39. A method of amplifying a nucleic acid test sample comprising priming a nucleic acid polymerase chain reaction with the nucleic acid of claim 28.
40. A method for purifying a heregulin comprising adsorbing heregulin from a contaminated solution thereof onto heparin Sepharose or a cation exchange resin.
- 25

1 / 32

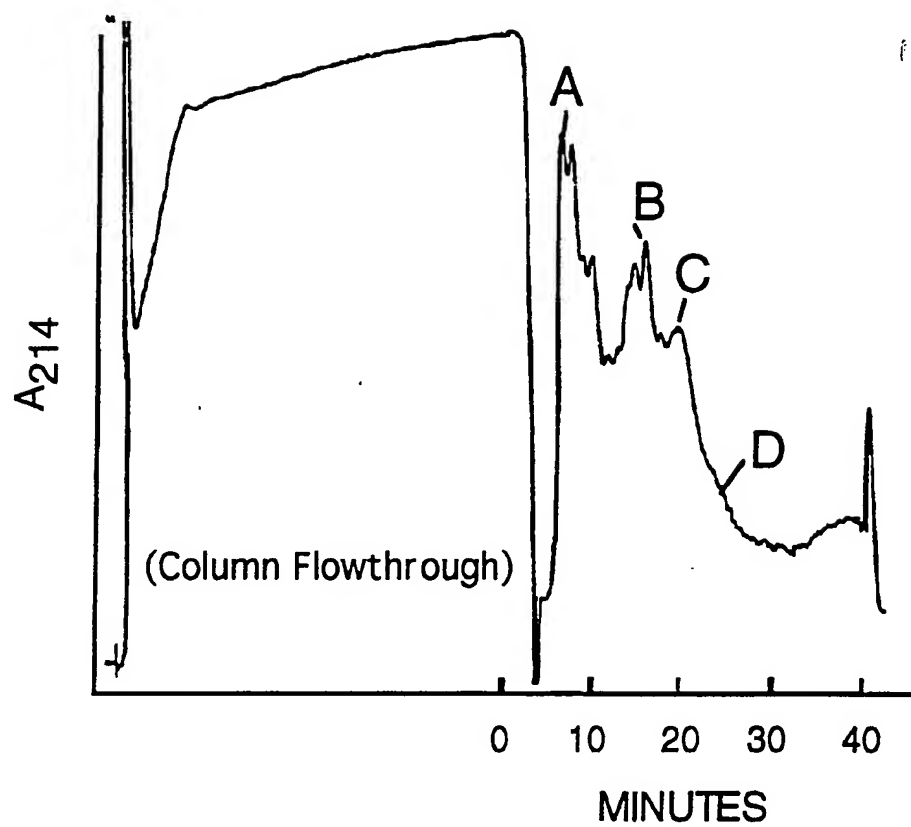
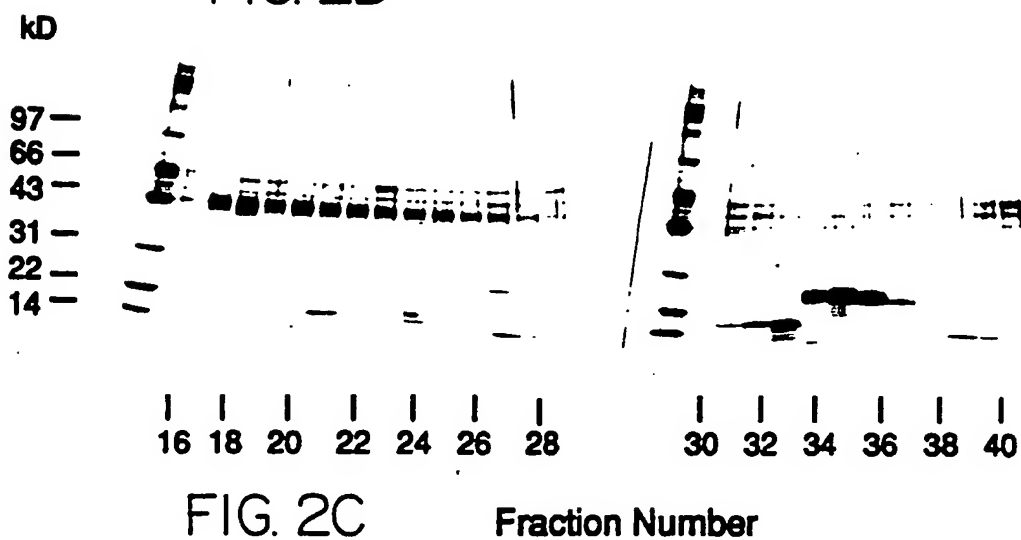
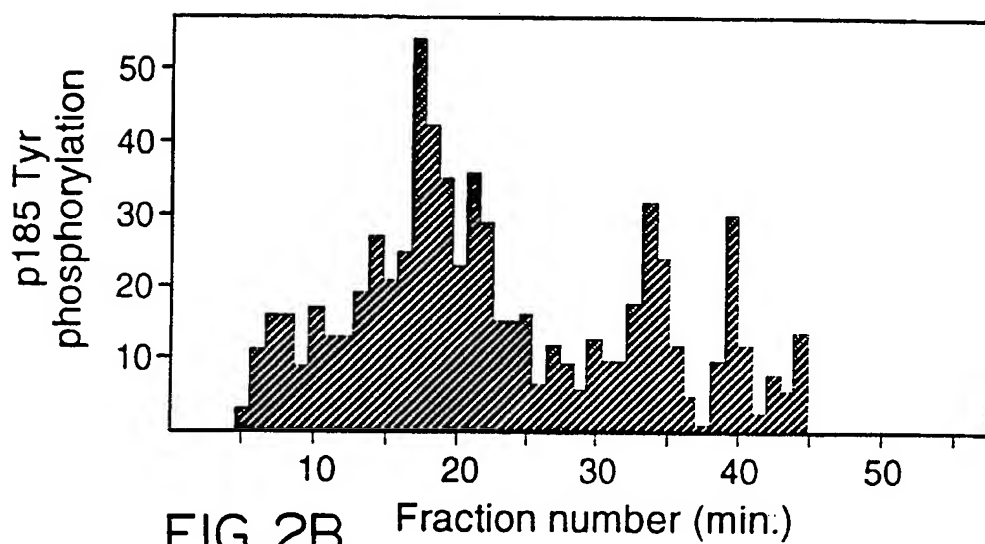
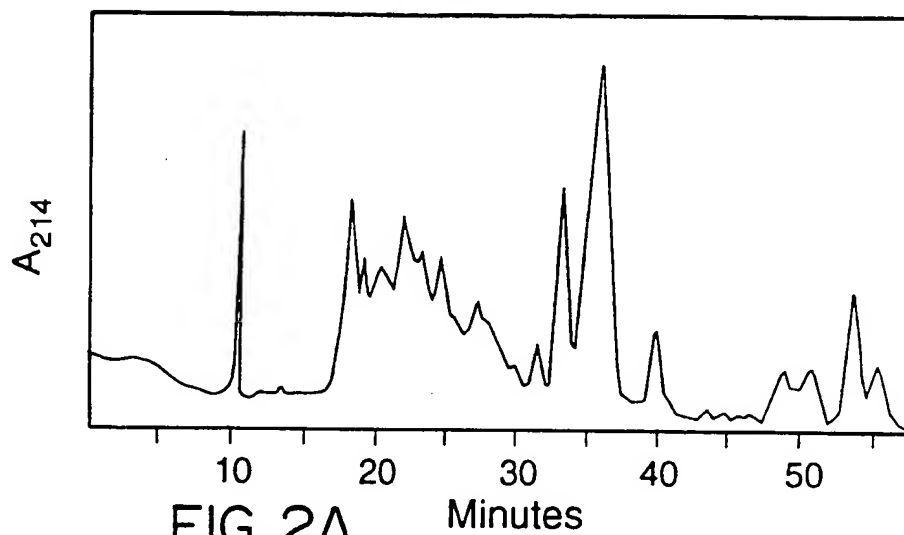


FIG. 1

SUBSTITUTE SHEET

2 / 32



SUBSTITUTE SHEET



3 / 32

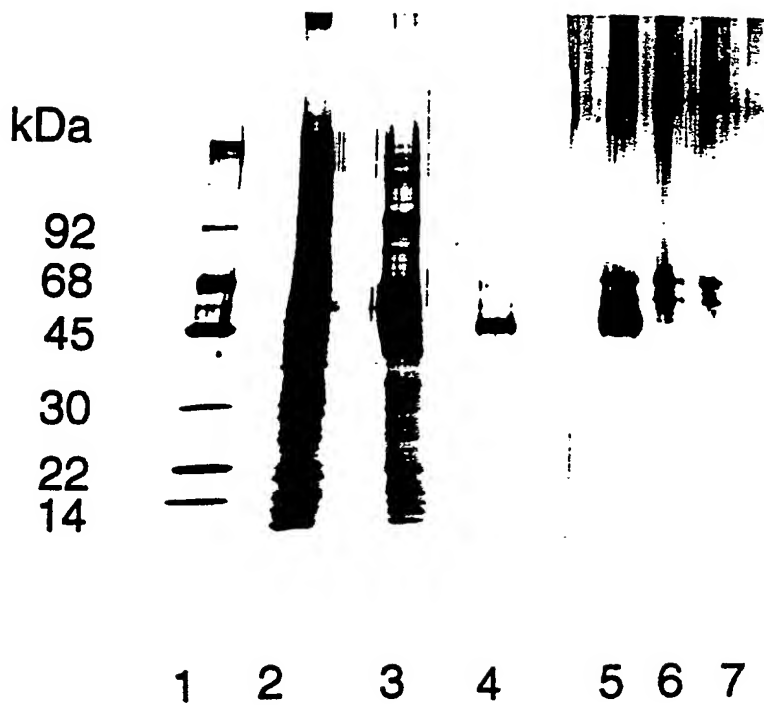


FIG. 3

SUBSTITUTE SHEET

4 / 32

GG GCG CGA GCG CCT CAG CGC GGC CGC TCG CTC TCC CCC 38  
 Ala Arg Ala Pro Gln Arg Gly Arg Ser Leu Ser Pro  
 1 5 10

TCG AGG GAC AAA CTT TTC CCA AAC CCG ATC CGA GCC CTT 77  
 Ser Arg Asp Lys Leu Phe Pro Asn Pro Ile Arg Ala Leu  
 15 20 25

GGA CCA AAC TCG CCT GCG CCG AGA GCC GTC CGC GTA GAG 116  
 Gly Pro Asn Ser Pro Ala Pro Arg Ala Val Arg Val Glu  
 30 35

CGC TCC GTC TCC GGC GAG ATG TCC GAG CGC AAA GAA GGC 155  
 Arg Ser Val Ser Gly Glu Met Ser Glu Arg Lys Glu Gly  
 40 45 50

AGA GGC AAA GGG AAG GGC AAG AAG AAG GAG CGA GGC TCC 194  
 Arg Gly Lys Gly Lys Gly Lys Lys Lys Glu Arg Gly Ser  
 55 60

GGC AAG AAG CCG GAG TCC GCG GCG GGC AGC CAG AGC CCA 233  
 Gly Lys Lys Pro Glu Ser Ala Ala Gly Ser Gln Ser Pro  
 65 70 75

GCC TTG CCT CCC CGA TTG AAA GAG ATG AAA AGC CAG GAA 272  
 Ala Leu Pro Pro Arg Leu Lys Glu Met Lys Ser Gln Glu  
 80 85 90

TCG GCT GCA GGT TCC AAA CTA GTC CTT CGG TGT GAA ACC 311  
 Ser Ala Ala Gly Ser Lys Leu Val Leu Arg Cys Glu Thr  
 95 100

AGT TCT GAA TAC TCC TCT CTC AGA TTC AAG TGG TTC AAG 350  
 Ser Ser Glu Tyr Ser Ser Leu Arg Phe Lys Trp Phe Lys  
 105 110 115

AAT GGG AAT GAA TTG AAT CGA AAA AAC AAA CCA CAA AAT 389  
 Asn Gly Asn Glu Leu Asn Arg Lys Asn Lys Pro Gln Asn  
 120 125

ATC AAG ATA CAA AAA AAG CCA GGG AAG TCA GAA CTT CGC 428  
 Ile Lys Ile Gln Lys Lys Pro Gly Lys Ser Glu Leu Arg  
 130 135 140

ATT AAC AAA GCA TCA CTG GCT GAT TCT GGA GAG TAT ATG 467  
 Ile Asn Lys Ala Ser Leu Ala Asp Ser Gly Glu Tyr Met  
 145 150 155

TGC AAA GTG ATC AGC AAA TTA GGA AAT GAC AGT GCC TCT 506  
 Cys Lys Val Ile Ser Lys Leu Gly Asn Asp Ser Ala Ser  
 160 165

FIG. 4A

5 / 32

GCC AAT ATC ACC ATC GTG GAA TCA AAC GAG ATC ATC ACT 545  
 Ala Asn Ile Thr Ile Val Glu Ser Asn Glu Ile Ile Thr  
 170 175 180

GGT ATG CCA GCC TCA ACT GAA GGA GCA TAT GTG TCT TCA 584  
 Gly Met Pro Ala Ser Thr Glu Gly Ala Tyr Val Ser Ser  
 185 190

GAG TCT CCC ATT AGA ATA TCA GTA TCC ACA GAA GGA GCA 623  
 Glu Ser Pro Ile Arg Ile Ser Val Ser Thr Glu Gly Ala  
 195 200 205

AAT ACT TCT TCA TCT ACA TCT ACA TCC ACC ACT GGG ACA 662  
 Asn Thr Ser Ser Ser Thr Ser Thr Ser Thr Thr Gly Thr  
 210 215 220

AGC CAT CTT GTA AAA TGT GCG GAG AAG GAG AAA ACT TTC 701  
 Ser His Leu Val Lys Cys Ala Glu Lys Glu Lys Thr Phe  
 225 230

TGT GTG AAT GGA GGG GAG TGC TTC ATG GTG AAA GAC CTT 740  
 Cys Val Asn Gly Gly Glu Cys Phe Met Val Lys Asp Leu  
 235 240 245

TCA AAC CCC TCG AGA TAC TTG TGC AAG TGC CAA CCT GGA 779  
 Ser Asn Pro Ser Arg Tyr Leu Cys Lys Cys Gln Pro Gly  
 250 255

TTC ACT GGA GCA AGA TGT ACT GAG AAT GTG CCC ATG AAA 818  
 Phe Thr Gly Ala Arg Cys Thr Glu Asn Val Pro Met Lys  
 260 265 270

GTC CAA AAC CAA GAA AAG GCG GAG GAG CTG TAC CAG AAG 857  
 Val Gln Asn Gln Glu Lys Ala Glu Glu Leu Tyr Gln Lys  
 275 280 285

AGA GTG CTG ACC ATA ACC GGC ATC TGC ATC GCC CTC CTT 896  
 Arg Val Leu Thr Ile Thr Gly Ile Cys Ile Ala Leu Leu  
 290 295

GTG GTC GGC ATC ATG TGT GTG GTG GCC TAC TGC AAA ACC 935  
 Val Val Gly Ile Met Cys Val Val Ala Tyr Cys Lys Thr  
 300 305 310

AAG AAA CAG CGG AAA AAG CTG CAT GAC CGT CTT CGG CAG 974  
 Lys Lys Gln Arg Lys Lys Leu His Asp Arg Leu Arg Gln  
 315 320

AGC CTT CGG TCT GAA CGA AAC AAT ATG ATG AAC ATT GCC 1013  
 Ser Leu Arg Ser Glu Arg Asn Asn Met Met Asn Ile Ala  
 325 330 335

FIG. 4B

SUBSTITUTE SHEET

6 / 32

AAT	GGG	CCT	CAC	CAT	CCT	AAC	CCA	CCC	CCC	GAG	AAT	GTC	1052
Asn	Gly	Pro	His	His	Pro	Asn	Pro	Pro	Pro	Glu	Asn	Val	
		340					345					350	
CAG	CTG	GTG	AAT	CAA	TAC	GTA	TCT	AAA	AAC	GTC	ATC	TCC	1091
Gln	Leu	Val	Asn	Gln	Tyr	Val	Ser	Lys	Asn	Val	Ile	Ser	
			355						360				
AGT	GAG	CAT	ATT	GTT	GAG	AGA	GAA	GCA	GAG	ACA	TCC	TTT	1130
Ser	Glu	His	Ile	Val	Glu	Arg	Glu	Ala	Glu	Thr	Ser	Phe	
	365					370					375		
TCC	ACC	AGT	CAC	TAT	ACT	TCC	ACA	GCC	CAT	CAC	TCC	ACT	1169
Ser	Thr	Ser	His	Tyr	Thr	Ser	Thr	Ala	His	His	Ser	Thr	
			380					385					
ACT	GTC	ACC	CAG	ACT	CCT	AGC	CAC	AGC	TGG	AGC	AAC	GGA	1208
Thr	Val	Thr	Gln	Thr	Pro	Ser	His	Ser	Trp	Ser	Asn	Gly	
390					395					400			
CAC	ACT	GAA	AGC	ATC	CTT	TCC	GAA	AGC	CAC	TCT	GTA	ATC	1247
His	Thr	Glu	Ser	Ile	Leu	Ser	Glu	Ser	His	Ser	Val	Ile	
		405					410					415	
GTG	ATG	TCA	TCC	GTA	GAA	AAC	AGT	AGG	CAC	AGC	AGC	CCA	1286
Val	Met	Ser	Ser	Val	Glu	Asn	Ser	Arg	His	Ser	Ser	Pro	
				420					425				
ACT	GGG	GGC	CCA	AGA	GGA	CGT	CTT	AAT	GGC	ACA	GGA	GGC	1325
Thr	Gly	Gly	Pro	Arg	Gly	Arg	Leu	Asn	Gly	Thr	Gly	Gly	
	430					435					440		
CCT	CGT	GAA	TGT	AAC	AGC	TTC	CTC	AGG	CAT	GCC	AGA	GAA	1364
Pro	Arg	Glu	Cys	Asn	Ser	Phe	Leu	Arg	His	Ala	Arg	Glu	
			445					450					
ACC	CCT	GAT	TCC	TAC	CGA	GAC	TCT	CCT	CAT	AGT	GAA	AGG	1403
Thr	Pro	Asp	Ser	Tyr	Arg	Asp	Ser	Pro	His	Ser	Glu	Arg	
455					460					465			
TAT	GTG	TCA	GCC	ATG	ACC	ACC	CCG	GCT	CGT	ATG	TCA	CCT	1442
Tyr	Val	Ser	Ala	Met	Thr	Thr	Pro	Ala	Arg	Met	Ser	Pro	
		470					475					480	
GTA	GAT	TTC	CAC	ACG	CCA	AGC	TCC	CCC	AAA	TCG	CCC	CCT	1481
Val	Asp	Phe	His	Thr	Pro	Ser	Ser	Pro	Lys	Ser	Pro	Pro	
				485					490				
TCG	GAA	ATG	TCT	CCA	CCC	GTG	TCC	AGC	ATG	ACG	GTG	TCC	1520
Ser	Glu	Met	Ser	Pro	Pro	Val	Ser	Ser	Met	Thr	Val	Ser	
	495					500					505		

FIG. 4C

SUBSTITUTE SHEET

7 / 32

ATG	CCT	TCC	ATG	GCG	GTC	AGC	CCC	TTC	ATG	GAA	GAA	GAG	1559
Met	Pro	Ser	Met	Ala	Val	Ser	Pro	Phe	Met	Glu	Glu	Glu	
			510					515					

AGA	CCT	CTA	CTT	CTC	GTG	ACA	CCA	CCA	AGG	CTG	CGG	GAG	1598
Arg	Pro	Leu	Leu	Leu	Val	Thr	Pro	Pro	Arg	Leu	Arg	Glu	
520					525					530			

AAG	AAG	TTT	GAC	CAT	CAC	CCT	CAG	CAG	TTC	AGC	TCC	TTC	1637
Lys	Lys	Phe	Asp	His	His	Pro	Gln	Gln	Phe	Ser	Ser	Phe	
		535					540					545	

CAC	CAC	AAC	CCC	GCG	CAT	GAC	AGT	AAC	AGC	CTC	CCT	GCT	1676
His	His	Asn	Pro	Ala	His	Asp	Ser	Asn	Ser	Leu	Pro	Ala	
				550					555				

AGC	CCC	TTG	AGG	ATA	GTG	GAG	GAT	GAG	GAG	TAT	GAA	ACG	1715
Ser	Pro	Leu	Arg	Ile	Val	Glu	Asp	Glu	Glu	Tyr	Glu	Thr	
	560					565					570		

ACC	CAA	GAG	TAC	GAG	CCA	GCC	CAA	GAG	CCT	GTT	AAG	AAA	1754
Thr	Gln	Glu	Tyr	Glu	Pro	Ala	Gln	Glu	Pro	Val	Lys	Lys	
			575					580					

CTC	GCC	AAT	AGC	CGG	CGG	GCC	AAA	AGA	ACC	AAG	CCC	AAT	1793
Leu	Ala	Asn	Ser	Arg	Arg	Ala	Lys	Arg	Thr	Lys	Pro	Asn	
585					590					595			

GGC	CAC	ATT	GCT	AAC	AGA	TTG	GAA	GTG	GAC	AGC	AAC	ACA	1832
Gly	His	Ile	Ala	Asn	Arg	Leu	Glu	Val	Asp	Ser	Asn	Thr	
		600					605					610	

AGC	TCC	CAG	AGC	AGT	AAC	TCA	GAG	AGT	GAA	ACA	GAA	GAT	1871
Ser	Ser	Gln	Ser	Ser	Asn	Ser	Glu	Ser	Glu	Thr	Glu	Asp	
				615					620				

GAA	AGA	GTA	GGT	GAA	GAT	ACG	CCT	TTC	CTG	GGC	ATA	CAG	1910
Glu	Arg	Val	Gly	Glu	Asp	Thr	Pro	Phe	Leu	Gly	Ile	Gln	
	625					630					635		

AAC	CCC	CTG	GCA	GCC	AGT	CTT	GAG	GCA	ACA	CCT	GCC	TTC	1949
Asn	Pro	Leu	Ala	Ala	Ser	Leu	Glu	Ala	Thr	Pro	Ala	Phe	
			640					645					

CGC	CTG	GCT	GAC	AGC	AGG	ACT	AAC	CCA	GCA	GGC	CGC	TTC	1988
Arg	Leu	Ala	Asp	Ser	Arg	Thr	Asn	Pro	Ala	Gly	Arg	Phe	
650					655					660			

TCG	ACA	CAG	GAA	GAA	ATC	CAG	G	2010					
Ser	Thr	Gln	Glu	Glu	Ile	Gln							
			665			669							

FIG. 4D

8 / 32

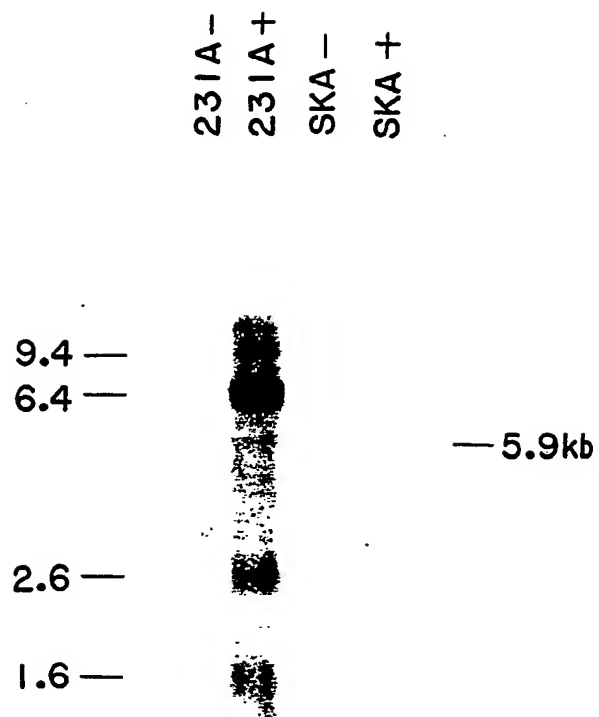


FIG. 5

SUBSTITUTE SHEET

9/32.

HRG2-alpha	221	S	H	L	V	K	C	A	E	K	E	K	T	F	C	V	N	G	G	E	C	F	M	V	K	D	L	S	N	P	S	R	Y	L	C	K	C	Q	P	G	F	T	G	A	R	C	T	E	N	
EGF		N	S	D	S	E	C	P	L	S	H	D	G	Y	C	L	H	D	G	V	C	M	Y	I	E	A	L	-	-	-	D	K	Y	A	C	N	C	V	V	G	Y	I	G	E	R	C	Q	Y	R	
TGF-alpha							N	D	C	P	D	S	H	T	Q	F	F	H	-	G	T	C	R	F	L	V	Q	E	-	-	-	D	K	P	A	C	V	C	H	S	G	Y	V	G	A	R	C	E	H	A
Amphiregulin		K	K	K	N	P	C	N	A	E	F	Q	N	F	C	I	H	-	G	E	C	K	Y	I	E	H	L	-	-	-	E	A	V	T	C	K	C	Q	Q	E	Y	F	G	E	R	C	G	E	K	
Schwannoma		K	K	K	N	P	C	A	A	K	F	Q	N	F	C	I	H	-	G	E	C	R	Y	I	E	N	L	-	-	-	E	V	T	C	H	C	H	Q	D	Y	F	G	E	R	C	G	E	K		
HB-EGF		K	K	R	D	P	C	L	R	K	Y	K	D	F	C	I	H	-	G	E	C	K	Y	V	K	E	L	-	-	-	R	A	P	S	C	I	C	H	P	G	Y	H	G	E	R	C	H	G	L	

HRG2-alpha	270	V	P	M	K	V	Q	N	Q	E	K	A	E	E	L	Y	Q	K	R	V	L	T	I	T	G	I	C	I	A	L	L	V	V	G	I	M	C	V	V	A	Y	C	K	T	K	K	Q	R	.
EGF		D	L	K	W	E	L	R	H	A	G	H	G	Q	Q	-	K	-	-	V	I	V	V	A	V	C	V	V	L	V	M	L	L	L	L	L	S	L	W	G	A	H	Y	Y	R	T	Q	K	
TGF-alpha		D	L	L	A	V	A	S	Q	K	-	-	-	-	-	-	-	-	-	Q	A	I	T	A	L	V	V	S	I	V	A	L	A	V	L	I	I	T	C	V	L	I	H	C	C	Q	V		
Amphiregulin		S	M	K	T	H	S	M	I	D	S	S	L	S	-	-	-	-	-	I	A	L	A	I	A	A	F	M	S	A	V	I	L	T	A	V	A	V	I	T	V	Q	L	R	R	Q	Y		
Schwannoma		T	M	K	T	Q	K	K	D	D	S	D	L	S	-	-	-	-	-	I	A	L	A	I	I	V	F	V	S	A	V	S	V	A	A	I	G	I	I	T	A	V	L	L	R	K	R		
HB-EGF		S	L	P	V	E	N	R	L	Y	T	Y	D	-	-	-	-	-	-	H	T	T	I	L	A	V	V	A	V	V	L	S	S	V	C	L	L	V	I	V	G	L	L	M	F	R	Y	H	R

TRANSMEMBRANE REGION

FIG. 6

10/32

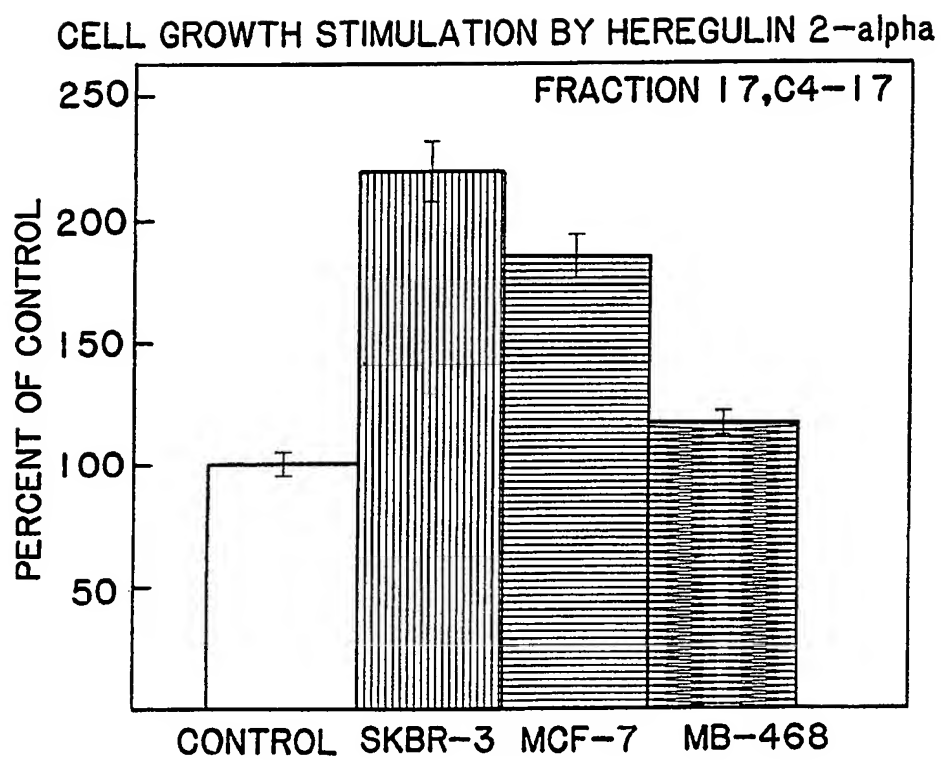
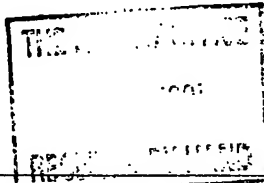


FIG. 7

SUBSTITUTE SHEET



For official use



10 APR 1991

Your reference

APUK91347

9107566.3

#### Notes

Please type, or write in dark ink using CAPITAL letters. A prescribed fee is payable for a request for grant of a patent. For details, please contact the Patent Office (telephone 071-829 6910).

Rule 6 of the Patents Rules 1990 is the main rule governing the completion and filing of this form.

Do not give trading styles, for example, 'Trading as XYZ company', nationality or former names, for example, 'formerly (known as) ABC Ltd' as these are not required.

#### Warning

If an application for a Patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977 and will inform the applicant if such prohibition or restriction is necessary. Applicants resident in the United Kingdom are also reminded that under Section 23, applications may not be filed abroad without written permission unless an application has been filed not less than 6 weeks previously in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction revoked.

**The  
Patent  
Office**

## Request for grant of a Patent

Form 1/77

Patents Act 1977

### 1 Title of invention

- 1 Please give the title of the invention GLIAL MITOGENIC FACTORS, THEIR PREPARATION AND USE

### 2 Applicant's details

#### ☐ First or only applicant

- 2a If you are applying as a corporate body please give:

Corporate name LUDWIG INSTITUTE FOR CANCER RESEARCH

Country (and State of incorporation, if appropriate) SWITZERLAND

- 2b If you are applying as an individual or one of a partnership please give in full:

Surname

Forenames

- 2c In all cases, please give the following details:

Address  
ST MARY'S HOSPITAL MEDICAL SCHOOL  
NORFOLK PLACE  
PADDINGTON  
LONDON

UK postcode (if applicable) W2 1PG

Country UK

ADP number (if known)

5256919001 JF

**2d, 2e and 2f:** If there are further applicants please provide details on a separate sheet of paper.

☐ **Second applicant (if any)**

**2d** If you are applying as a corporate body please give:

Corporate name

Country (and State  
of incorporation, if  
appropriate)

**2e** If you are applying as an individual or one of a partnership please give in full:

Surname

Forenames

**2f** In all cases, please give the following details:

Address

UK postcode  
(if applicable)

Country

ADP number  
(if known)

**③** An address for service in the United Kingdom must be supplied

Please mark correct box

**③ Address for service details**

**3a** Have you appointed an agent to deal with your application?

Yes ☒ No ☐ → go to 3b

↓  
please give details below

Agent's name  
HEPWORTH LAWRENCE BRYER & BIZLEY

Agent's address  
2ND FLOOR GATE HOUSE SOUTH  
WEST GATE  
HARLOW  
ESSEX

Postcode CM20 1JN

Agent's ADP  
number 1910801  
5011785002AP

**3b:** If you have appointed an agent, all correspondence concerning your application will be sent to the agent's United Kingdom address.

**3b** If you have not appointed an agent please give a name and address in the United Kingdom to which all correspondence will be sent:

Name

Address

Postcode

ADP number  
(if known)

Daytime telephone  
number (if available)

**4 Reference number**

4 Agent's or  
applicant's reference  
number (if applicable) APUK91347

**5 Claiming an earlier application date**

5 Are you claiming that this application be treated as having been filed on the date of filing of an earlier application?

Yes ☐ No ☒ → go to 6

↓  
please give details below

☐ number of earlier  
application or patent  
number

☐ filing date  
(day month year)

☐ and the Section of the Patents Act 1977 under which you are claiming:

15(4) (Divisional) ☐ 8(3) ☐ 12(6) ☐ 37(4) ☐

**6 Declaration of priority**

6 If you are declaring priority from previous application(s), please give:

Country of filing	Priority application number (if known)	Filing date (day, month, year)
-------------------	---	-----------------------------------

⑥ If you are declaring priority from a  
PCT Application please enter 'PCT' as  
the country and enter the country  
code (for example, GB) as part of the  
application number.

Please give the date in all number  
format, for example, 31/05/90 for  
31 May 1990.

- 7 The answer must be 'No' if:
- any applicant is not an inventor
  - there is an inventor who is not an applicant, or
  - any applicant is a corporate body.

8 Please supply duplicates of claim(s), abstract, description and drawing(s).

Please mark correct box(es)

- 9 You or your appointed agent (see Rule 90 of the Patents Rules 1990) must sign this request.

Please sign here →

A completed fee sheet should preferably accompany the fee.

## 7 Inventorship

7 Are you (the applicant or applicants) the sole inventor or the joint inventors?

Please mark correct box

Yes ☐

No ☒

A Statement of Inventorship on Patents Form 7/77 will need to be filed (see Rule 15).

## 8 Checklist

8a Please fill in the number of sheets for each of the following types of document contained in this application.

Continuation sheets for this Patents Form 1/77

Claim(s)

5

Description

19

Abstract

1

Drawing(s)

8

8b Which of the following documents also accompanies the application?

Priority documents (please state how many)

Translation(s) of Priority documents (please state how many)

Patents Form 7/77 – Statement of Inventorship and Right to Grant  
(please state how many)

Patents Form 9/77 – Preliminary Examination/Search

Patents Form 10/77 – Request for Substantive Examination

## 9 Request

I/We request the grant of a patent on the basis of this application.

Signed

Date 10 April 1991  
(day month year)

Please return the completed form, attachments and duplicates where requested, together with the prescribed fee to:

☐ The Comptroller  
The Patent Office  
State House  
66–71 High Holborn  
London  
WC1R 4TP

Glial Mitogenic Factors, Their Preparation and Use

05 This invention relates to new polypeptides characteristic of vertebrate species, which polypeptides are mitogenic growth factors having activity on cultured Schwann cells. The invention is also concerned, inter alia, with a novel isolation process capable of producing such factors, and the therapeutic application of such factors.

10 The glial cells of vertebrates constitute the specialized connective tissue of the central and peripheral nervous systems. Important glial cells include Schwann cells which provide myelin sheathing around the axons of neurones, thereby forming individual nerve fibres. Schwann  
15 cells provide a sheath effect by forming concentric layers of membrane around adjacent neurone axons, twisting as they develop around the axons. These myelin sheaths are a susceptible element of many nerve fibres, and damage to Schwann cells, or failure in growth and development, can be  
20 associated with significant demyelination or nerve degeneration characteristic of a number of central and peripheral nervous system diseases and disorders. In the development of the nervous system, it has become apparent  
25 that cells require various factors to regulate their division and growth, and various such factors have been identified in recent years, including some found to have an effect on Schwann cell division or development.

30 Thus, Brockes et al., inter alia, in J. Neuroscience, 4 (1984), No. 1, 75-83 describe a protein growth factor present in extracts from bovine brain and pituitary tissue, which was named Glial Growth Factor (GGF). GGF stimulated cultured rat Schwann cells to divide against a background  
35 medium containing ten percent foetal calf serum. GGF is

also described as having a molecular weight of 31,000 and as readily dimerizing. In Meth. Enz., 147 (1987), 217-225, Brockes describes a Schwann cell-based assay for GGF, and emphasises that in purification of the factor the use  
05 of reversed-phase HPLC using trifluoroacetic acid as an ion pairing agent must be avoided if biological activity is to be retained.

The J. Neuroscience article of Brockes et al., supra,  
10 describes methods of purification of GGF to apparent homogeneity. In brief, one large-scale purification method described involves extraction of the lyophilized bovine anterior lobes and chromatography of material obtained thereby using NaCl gradient elution from CM-cellulose. Gel  
15 filtration is then carried out with an Ultrogel column, followed by elution from a phosphocellulose column, and finally, small-scale SDS gel electrophoresis. Alternatively, the CM-cellulose material was applied directly to a phosphocellulose column, fractions from the  
20 column were pooled and purified by preparative native gel electrophoresis, followed by a final SDS gel electrophoresis.

Brockes et al. observe that in previously reported gel  
25 filtration experiments (Brockes et al., J. Biol. Chem. 255 (1980) 8374-8377), the major peak of growth factor activity was observed to migrate with a molecular weight of 56,000, whereas in the first of the above-described procedures activity was predominantly observed at molecular weight  
30 31,000. It is reported that the GGF dimer is largely removed as a result of the gradient elution from CM-cellulose in this procedure.

In PNAS, 82 (1985), 3930-3934, Benveniste et al.  
35 describe a T lymphocyte-derived glial growth promoting

factor. This factor, under reducing conditions, exhibits a change in apparent molecular weight on SDS gels.

05 In Nature, 348 (1990), 257-260, Kimura et al. describe  
a factor they term Schwannoma-derived growth factor (SDGF)  
obtained from a sciatic nerve sheath tumour. The authors  
state that SDGF does not stimulate the incorporation of  
tritium-labelled TdR into cultured Schwann cells under  
conditions where, in contrast, partially purified pituitary  
10 fraction containing GGF is active. SDGF has an apparent  
molecular weight of between 31,000 and 35,000.

In J. Cell. Biol., 110 (1990), 1353-1360, Davis et al.  
describe the screening of a number of candidate mitogens.  
15 Rat Schwann cells were used, the chosen candidate  
substances being examined for their ability to stimulate  
DNA synthesis in the Schwann cells in the presence of 10%  
FCS (foetal calf serum), with and without forskolin. One  
of the factors tested was GGF-carboxymethyl cellulose  
20 fraction (GGF-CM), which was mitogenic in the presence of  
FCS, with and without forskolin. The work revealed that  
in the presence of forskolin, inter alia, platelet derived  
growth factor (PDGF) was a potent mitogen for Schwann  
cells, PDGF having previously been thought to have no  
25 effect on Schwann cells.

This invention is based upon the discovery of new  
glial growth factors which are distinguished from known  
factors, including the above, which factors are mitogenic  
30 for Schwann cells against a background of foetal calf  
plasma (FCP). The invention also provides a process for  
preparation of these factors, and an improved method for  
defining activity of these and other factors. Therapeutic  
application of the factors is a further significant aspect  
35 of the invention.

Thus, in one aspect the invention provides a basic polypeptide factor which has, if obtained from bovine pituitary material, an observed molecular weight, whether  
05 in reducing conditions or not, of from about 30 kD to about 36 kD on SDS-polyacrylamide gel electrophoresis using the following molecular weight standards:

	Lysozyme (hen egg white)	14,400
10	Soybean trypsin inhibitor	21,500
	Carbonic anhydrase (bovine)	31,000
	Ovalbumin (hen egg white)	45,000
	Bovine serum albumin	66,200
	Phosphorylase B (rabbit muscle)	97,400;

15 which factor has mitogenic activity stimulating the division of rat Schwann cells in the presence of foetal calf plasma, and when isolated using reversed-phase HPLC retains at least 50% of said activity after 10 weeks  
20 incubation in 0.1% trifluoroacetic acid at 4°C. For convenience, this factor is termed "Factor-I" hereinafter.

In another aspect, the invention provides a basic polypeptide factor which has, if obtained from bovine  
25 pituitary material, an observed molecular weight, under non-reducing conditions, of from about 55 kD to about 63 kD on SDS-polyacrylamide gel electrophoresis using the following molecular weight standards:

30	Lysozyme (hen egg white)	14,400
	Soybean trypsin inhibitor	21,500
	Carbonic anhydrase (bovine)	31,000
	Ovalbumin (hen egg white)	45,000
	Bovine serum albumin	66,200
35	Phosphorylase B (rabbit muscle)	97,400;



which factor has mitogenic activity stimulating the division of rat Schwann cells in the presence of foetal calf plasma, and when isolated using reversed-phase HPLC  
05 retains at least 50% of said activity after 4 days incubation in 0.1% trifluoroacetic acid at 4°C. For convenience, this factor is "Factor-II" hereinafter.

10 It will be appreciated that the molecular weight range limits quoted are not exact, but are subject to slight variation depending, inter alia, upon the source of the particular polypeptide factor. A variation of, say, about 10% would not, for example, be impossible for material from another source.

15 The invention includes any modifications or equivalents of the above two polypeptide factors which do not exhibit a significantly reduced activity. For example, modifications in which amino acid content or sequence is  
20 altered without substantially adversely affecting activity are included. By way of illustration, in EP-A-109748 muteins of native proteins are disclosed in which the possibility of unwanted -S-S- bonding is avoided by replacing any cysteine in the native sequence not necessary  
25 for biological activity with a neutral amino acid. The statements of effect and use contained herein are therefore to be construed accordingly, with such uses and effects employing modified or equivalent factors as aforesaid being part of the invention.

30 None of the factors described in the art has the combination of characteristics possessed by the present new polypeptide factors.

35 As indicated, the Schwann cell assay in part used to

characterise the present factors employs a background of foetal calf plasma. In all other respects, the assay can be the same as that described by Brockes et al. in Meth. Enz., supra, but with 10% FCP replacing 10% FCS. This difference in assay technique is significant, since the absence of platelet-derived factors in foetal calf plasma (as opposed to serum) enables a more rigorous definition of activity on Schwann cells to be provided by eliminating potentially spurious effects from some other factors.

A further aspect of the invention is a process for the preparation of a polypeptide as defined above, comprising extracting vertebrate brain material to obtain protein, subjecting the resulting extract to chromatographic purification comprising hydroxylapatite HPLC and thereafter to SDS-polyacrylamide gel electrophoresis and collecting that fraction therefrom which has an observed molecular weight of about 30 kD to 36 kD and/or that fraction which has an observed molecular weight of about 55 kD to 63 kD if, in either case, subjected to SDS-polyacrylamide gel electrophoresis using the following molecular weight standards:

	Lysozyme (hen egg white)	14,400
25	Soybean trypsin inhibitor	21,500
	Carbonic anhydrase (bovine)	31,000
	Ovalbumin (hen egg white)	45,000
	Bovine serum albumin	66,200
	Phosphorylase B (rabbit muscle)	97,400;

in the case of the aforesaid smaller molecular weight fraction whether in reducing conditions or not, and in the case of the aforesaid larger molecular weight fraction under non-reducing conditions, and which fraction(s) exhibit(s) activity stimulating the division of rat Schwann

cells against a background of foetal calf plasma.

Preferably, the above process starts by isolating a relevant fraction obtained by carboxymethyl cellulose chromatography, e.g. from bovine pituitary material. It is also preferred that after hydroxylapatite HPLC, cation exchange chromatography, gel filtration, and/or reversed-phase HPLC be employed prior to the SDS-polyacrylamide gel electrophoresis. At each stage in the process, activity may be determined using Schwann cell incorporation of radioactive iododeoxyuridine as a measure in an assay generally as described by Brockes in Meth. Enz., supra, but modified by substituting 10% FCP for 10% FCS. As already noted, such an assay is an aspect of the invention in its own right when applied generally to the assay of any substance for CNS or PNS cell, e.g. Schwann cell, mitogenic effects.

Thus, the invention also includes an assay for glial cell mitogenic activity in which a background of foetal calf plasma is employed against which to assess DNA synthesis in glial cells stimulated (if at all) by a substance under assay.

Another aspect of the invention is a pharmaceutical or veterinary formulation comprising a factor as defined above formulated for pharmaceutical or veterinary use, respectively, optionally together with an acceptable diluent, carrier or excipient and/or in unit dosage form. In using the factors of the invention, conventional pharmaceutical or veterinary practice may be employed to provide suitable formulations or compositions.

Thus, the formulations of this invention can be applied to parenteral administration, for example,

intravenous, subcutaneous, intramuscular, intraorbital,  
ophthalmic, intraventricular, intracranial, intracapsular,  
intraspinal, intracisternal, intraperitoneal, topical,  
intranasal, aerosol, scarification, and also oral, buccal,  
05 rectal or vaginal administration.

Parenteral formulations may be in the form of liquid  
solutions or suspensions; for oral administration,  
formulations may be in the form of tablets or capsules;  
10 and for intranasal formulations, in the form of powders,  
nasal drops, or aerosols.

Methods well known in the art for making formulations  
are to be found in, for example, "Remington's  
15 Pharmaceutical Sciences". Formulations for parenteral  
administration may, for example, contain as excipients  
sterile water or saline, polyalkylene glycols such as  
polyethylene glycol, oils of vegetable origin, or  
hydrogenated naphthalenes. Biocompatible, biodegradable  
20 lactide polymer, lactide/glycolide copolymer, or  
polyoxyethylene-polyoxypropylene copolymers may be used to  
control the release of the present factors. Other  
potentially useful parenteral delivery systems for the  
factors include ethylene-vinyl acetate copolymer particles,  
25 osmotic pumps, implantable infusion systems, and liposomes.  
Formulations for inhalation may contain as excipients, for  
example, lactose, or may be aqueous solutions containing,  
for example, polyoxyethylene-9-lauryl ether, glycocholate  
and deoxycholate, or may be oily solutions for  
30 administration in the form of nasal drops, or as a gel to  
be applied intranasally. Formulations for parenteral  
administration may also include glycocholate for buccal  
administration, methoxysalicylate for rectal  
administration, or citric acid for vaginal administration.

The present factors can be used as the sole active agents or can be used in combination with other active ingredients, e.g., other growth factors which could facilitate neuronal survival in neurological diseases, or  
05 peptidase or protease inhibitors.

The concentration of the present factors in the formulations of the invention will vary depending upon a number of issues, including the dosage to be administered,  
10 and the route of administration.

In general terms, the factors of this invention may be provided in an aqueous physiological buffer solution containing about 0.1 to 10% w/v compound for parenteral  
15 administration. General dose ranges are from about 1  $\mu$ g/kg to about 1 g/kg of body weight per day; a preferred dose range is from about 0.01 mg/kg to 100 mg/kg of body weight per day. The preferred dosage to be administered is likely to depend upon the type and extent of progression of the  
20 pathophysiological condition being addressed, the overall health of the patient, the make up of the formulation, and the route of administration.

As indicated above, Schwann cells (the glial cells of  
25 the peripheral nervous system) are stimulated to divide in the presence of the factors of the invention. Schwann cells of the peripheral nervous system are involved in creating the myelin sheath around individual nerve fibres which is important for proper conduction of electrical  
30 impulses to muscles and from sensory receptors.

There are a variety of peripheral neuropathies in which Schwann cells and nerve fibres are damaged, either primarily or secondarily. There are many neuropathies of  
35 both sensory and motor fibres (Adams and Victor, Principles

of Neurology). The most important of those neuropathies are probably the neuropathies associated with diabetes, Landry-Guillain-Barre syndrome, neuropathies caused by carcinomas, and neuropathies caused by toxic agents (some of which are used to treat carcinomas).

The invention, however, envisages treatment or prophylaxis of conditions where nervous system damage has been brought about by any basic cause, e.g. infection or injury. Thus, in addition to use of the present factors in the treatment of disorders or diseases of the nervous system where demyelination or loss of Schwann cells is present, such glial growth factors can be valuable in the treatment of disorders of the nervous system that have been caused by damage to the peripheral nerves. Following damage to peripheral nerves, the regeneration process is led by the growth or the re-establishment of Schwann cells, followed by the advancement of the nerve fibre back to its target. By speeding up the division of Schwann cells one could promote the regenerative process following damage.

Furthermore, there are a variety of tumours of glial cells the most common of which is probably neurofibromatosis, which is a patchy small tumour created by overgrowth of glial cells. Also, it has been found that an activity very much like GGF can be found in some Schwann cell tumours, and therefore an inhibitor of the action of the present factors on their receptors provides a therapy for glial tumours. The invention thus specifically includes a method for the prophylaxis or treatment of a glial tumour, which comprises administering an effective amount of a substance which inhibits the binding of a factor as defined above to a receptor therefor.

In general, the invention includes the use of present

polypeptide factors in the prophylaxis or treatment of any pathophysiological condition of the nervous system in which a factor-sensitive or factor-responsive cell type is involved.

05

The polypeptide factor of the invention can also be used as an immunogen for making antibodies such as monoclonal antibodies, following standard techniques. These antibodies can, in turn, be used for diagnostic purposes. Thus, conditions perhaps associated with abnormal levels of the factor may be tracked by using such antibodies. In vitro techniques can be used, employing assays on isolated samples using standard methods. Imaging methods can also be employed in which the antibodies are, for example, tagged with radioactive isotopes which can be imaged outside the body using techniques employed in the art of, for example, tumour imaging.

The invention also includes the general use of the present factors as glial cell mitogens in vivo or in vitro, and the factors for such use. One specific embodiment is thus a method for producing a glial cell mitogenic effect in a vertebrate by administering an effective amount of a factor of the invention. A preferred embodiment is such a method in the treatment or prophylaxis of a nervous system disease or disorder.

A further general aspect of the invention is the use of a factor of the invention in the manufacture of a medicament, preferably for the treatment of a nervous disease or disorder.

Also included in the invention are the use of the factors of the invention in competitive assays to identify or quantify molecules having receptor binding

characteristics corresponding to those of said polypeptides. The polypeptides may be labeled, optionally with a radioisotope. A competitive assay can identify both antagonists and agonists of the relevant receptor.

05

In another aspect, the invention provides the use of each one of the factors of the invention in an affinity isolation process, optionally affinity chromatography, for the separation of a respective corresponding receptor. Such processes for the isolation of receptors corresponding to particular proteins are known in the art, and a number of techniques are available and can be applied to the factors of the present invention. For example, in relation to IL-6 and IFN-gamma the reader is referred to Novick, D. et al., J. Chromatogr.; 1990, June 27; 510, 331-7, in relation to gonadotropin releasing hormone reference is made to Hazum, E., J. Chromatogr.; 1990, June 27; 510, 233-8, in relation to G-CSF reference is made to Fukunaga, R., et al., J. Biol. Chem.; 1990, Aug. 15; 265(23), 14008-15, in relation to vasoactive intestinal peptide reference is made to Couvineau, A., et al., J. Biol. Chem.; 1990, Aug. 5; 265(22), 13386-90, in relation to IL-2 reference is made to Smart, J.E., et al., J. Invest. Dermatol.; 1990, June; 94(6 Suppl.), 158S-163S, and in relation to human IFN-gamma reference is made to Stefanos, S., et al., J. Interferon Res.; 1989, Dec., 9(6), 719-30.

In the following description, techniques for obtaining Factor-I and/or Factor-II are described as an Example of the invention. In the accompanying drawings, Figures 1 to 6 are purification activity profiles obtained by using a modified assay method of Brockes et al. in Meth. Enz., supra, at various stages in the subsequently described process (see below), and Figures 7 and 8 are dose response curves illustrating the use of foetal calf plasma (as well

35



as foetal calf serum) as background in assaying activity.

Figure 1 is the profile for product from carboxymethyl cellulose chromatography;

05

Figure 2 is the profile for product from hydroxylapatite HPLC;

Figure 3 is the profile for product from Mono S FPLC;

10

Figure 4 is the profile for product from Gel filtration FPLC;

15 Figures 5 and 6 are the profiles for the two partially purified polypeptide products from reversed-phase HPLC; and

20 Figures 7 and 8 are dose response curves for the Factor-I and Factor-II fractions from reversed-phase HPLC using either a foetal calf serum or a foetal calf plasma background.

25 The following Example is not intended to limit the invention, but usefully illustrates the same, and provides specific guidance for effective preparative techniques. Unless otherwise indicated, all operations were conducted at 4°C.

30 In what follows, activity at each stage was determined using the Brockes (Meth. Enz., supra) techniques with the following modifications. Thus, in preparing Schwann cells, 5  $\mu$ M forskolin was added in addition to DMEM, FCS and GGF. Cells used in the assay were fibroblast-free Schwann cells at passage number less than 10, and these cells were  
35 removed from flasks with trypsin and plated into flat-

bottomed 96-well plates at 3.3 thousand cells per microwell. [ $^{125}\text{I}$ ]IUDR was added for the final 24 hours after test solution addition. The background (unstimulated) incorporation to each assay was less than 100 cpm, and maximal incorporation was 20 to 200 fold over background depending on Schwann cell batch and passage number.

In the case of the Factor-I and Factor-II fractions from reversed-phase HPLC as described below, two dose response curves were also produced for each factor, using exactly the above method for one of the curves for each factor, and the above method modified in the assay procedure only by substituting foetal calf plasma for foetal calf serum to obtain the other curve for each factor. The results are in Figures 7 and 8.

#### EXAMPLE

##### (A) Preparation of Factor-CM Fraction

4,000 frozen whole bovine pituitaries (c.a. 12 kg) were thawed overnight, washed briefly with water and then homogenised in an equal volume of 0.15 M ammonium sulphate in batches in a Waring Blendor. The homogenate was taken to pH 4.5 with 1.0 M HCl and centrifuged at 4,900 g for 80 minutes. Any fatty material in the supernatant was removed by passing it through glass wool. After taking the pH of the supernatant to 6.5 using 1.0 M NaOH, solid ammonium sulphate was added to give a 36% saturated solution. After several hours stirring, the suspension was centrifuged at 4,900 g for 80 minutes and the precipitate discarded. After filtration through glass wool, further solid ammonium sulphate was added to the supernatant to give a 75% saturated solution which was once again centrifuged at

4,900 g for 80 minutes after several hours stirring. The pellet was resuspended in c.a. 2 L of 0.1 M sodium phosphate pH 6.0 and dialysed 3 x 40 L of the same buffer. After confirming that the conductivity of the dialysate was below 20.0 mSiemens, it was loaded on to a Bioprocess column (120 x 113 mm, Pharmacia) packed with carboxymethyl cellulose (CM-52, Whatman) at a flow rate of 2 ml.min<sup>-1</sup>. The column was washed with 2 volumes of 0.1 M sodium phosphate pH 6.0, followed by 2 volumes of 50 mM NaCl, and finally 2 volumes of 0.2 M NaCl both in the same buffer. During this final step, 10 mL (5 minute) fractions were collected. Fractions 73 to 118 inclusive were pooled, dialysed against 10 volumes of 10 mM sodium phosphate pH 6.0 twice and clarified by centrifugation at 100,000 g for 60 minutes.

(B) Hydroxylapatite HPLC

Hydroxylapatite HPLC is not a technique hitherto used in isolating glial growth factors, but proved particularly efficacious in this invention.

The material obtained from the above CM-cellulose chromatography was filtered through a 0.22 µm filter (Nalgene), loaded at room temperature on to a high performance hydroxylapatite column (50 x 50 mm, Biorad) equipped with a guard column (15 x 25 mm, Biorad) and equilibrated with 10 mM potassium phosphate pH 6.0. Elution at room temperature was carried out at a flow rate of 2 mL.minute<sup>-1</sup> using the following programmed linear gradient:

time (min)	%B	Solvent A : 10 mM potassium phosphate pH 6.0
0.0	0	Solvent B : 1.0 M potassium phosphate pH 6.0
5.0	0	

	7.0	20
	70.0	20
	150.0	100
	180.0	100
05	185.0	0

6.0 mL (3 minute) fractions were collected during the gradient elution. Fractions 39-45 were pooled and dialysed against 10 volumes of 50 mM sodium phosphate pH 6.0.

10

(C) Mono S FPLC

Mono S FPLC enabled a more concentrated material to be prepared for subsequent gel filtration.

15

Any particulate material in the pooled material from the hydroxylapatite column was removed by a clarifying spin at 100,000 g for 60 minutes prior to loading on to a preparative HR10/10 Mono S cation exchange column (100 x 10 mm, Pharmacia) which was then re-equilibrated to 50 mM sodium phosphate pH 6.0 at room temperature with a flow rate of 1.0 mL.minute<sup>-1</sup>. Under these conditions, bound protein was eluted using the following programmed linear gradient:

25

	time (min)	%B	Solvent A : 50 mM potassium phosphate pH 6.0
	0.0	0	Solvent B : 1.2 M sodium chloride, 50 mM
	70.0	30	sodium phosphate pH 6.0
	240.0	100	
30	250.0	100	
	260.0	0	

1 mL (1 minute) fractions were collected throughout this gradient programme. Fractions 99 to 115 inclusive were pooled.

35

(D) Gel Filtration FPLC

05 This step commenced the separation of the two factors  
of the invention prior to final purification, producing  
enriched fractions.

10 For the purposes of this step, a preparative Superose  
12 FPLC column (510 x 20 mm, Pharmacia) was packed  
according to the manufacturers' instructions. In order to  
standardize this column, a theoretical plates measurement  
was made according to the manufacturers' instructions,  
giving a value of 9,700 theoretical plates.

15 The pool of Mono S eluted material was applied at room  
temperature in 2.5 mL aliquots to this column in 50 mM  
sodium phosphate, 0.75 NaCl pH 6.0 (previously passed  
through a C18 reversed phase column (Sep-pak, Millipore))  
at a flow rate of 1.0 mL.minute<sup>-1</sup>. 1 mL (0.5 minute)  
20 fractions were collected from 35 minutes after each sample  
was applied to the column. Fractions 27 to 41 (Factor-II)  
and 42 to 57 (Factor-I) inclusive from each run were  
pooled.

25 (E) Reversed-Phase HPLC

The Factor-I and Factor-II pools from the above  
Superose 12 runs were each divided into three equal  
aliquots. Each aliquot was loaded on to a C8 reversed-  
30 phase column (Aquapore RP-300 7  $\mu$  C8 220 x 4.6 mm, Applied  
Biosystems) protected by a guard cartridge (RP-8, 15 x 3.2  
mm, Applied Biosystems) and equilibrated to 40°C at 0.5  
mL.minute<sup>-1</sup>. Protein was eluted under these conditions  
using the following programmed linear gradient:

35

	time (min)	%B	Solvent A : 0.1% trifluoroacetic acid (TFA)
	0	0	Solvent B : 90% acetonitrile, 0.1% TFA
	60	66.6	
	62.0	100	
05	72.0	100	
	75.0	0	

200  $\mu$ L (0.4 minute) fractions were collected in  
siliconised tubes (Multilube tubes, Bioquote) from 15.2  
10 minutes after the beginning of the programmed gradient.

#### (F) SDS-Polyacrylamide Gel Electrophoresis

In this step, protein molecular weight standards, low  
15 range, catalogue no. 161-0304, from Bio-Rad Laboratories  
Limited, Watford, England were employed. The actual  
proteins used, and their molecular weight standards, have  
been listed hereinbefore.

Fractions 47 to 53 (Factor-I) and fractions 61 to 67  
(Factor-III) inclusive from the reversed-phase runs were  
individually pooled. 7  $\mu$ L of the pooled material was  
boiled in an equal volume of 0.125 M Tris-Cl, 4% SDS, 20%  
glycerol, and 10%  $\beta$ -mercaptoethanol for Factor-I, for 5  
25 minutes and loaded on to an 11% polyacrylamide Leammli gel  
with a 4% stacking gel and run at a constant voltage of 50  
V for 16 hours. This gel was then fixed and stained using  
a silver staining kit (Amersham). Under these conditions,  
the factors are each seen as a somewhat diffuse band at  
30 relative molecular weights 30,000 to 36,000 Daltons  
(Factor-I) and 55,000 to 63,000 Daltons (Factor-II) as  
defined by molecular weight markers. From the gel  
staining, it is apparent that there are a small number of  
other protein species present at equivalent levels to the  
35 Factor-I and Factor-II species in the material pooled from

the reversed-phase runs.

Stability in Trifluoroacetic Acid

05        Stability data were obtained for the present Factors  
in the presence of trifluoroacetic acid, as follows:-

Factor-I

10        Material from the reversed-phase HPLC, in the presence  
of 0.1% TFA and acetonitrile, was assayed within 12 hours  
of the completion of the column run and then after 10 weeks  
incubation at 4°C. Following incubation, the GGF-I had at  
least 50% of the activity of that material assayed directly  
off the column.

15

Factor-II

20        Material from the reversed-phase HPLC, in the presence  
of 0.1% TFA and acetonitrile, and stored at -20°C, was  
assayed after thawing and then after 4 days incubation at  
4°C. Following incubation, the GGF-II had at least 50% of  
the activity of that material freshly thawed.

25        It will be appreciated that the trifluoroacetic acid  
concentration used in the above studies is that most  
commonly used for reversed-phase chromatography.

30

35

CLAIMS

1. A basic polypeptide factor which has, if obtained from bovine pituitary material, an observed molecular weight, whether in reducing conditions or not, of from about 30 kD to about 36 kD on SDS-polyacrylamide gel electrophoresis using the following molecular weight standards:

	Lysozyme (hen egg white)	14,400
10	Soybean trypsin inhibitor	21,500
	Carbonic anhydrase (bovine)	31,000
	Ovalbumin (hen egg white)	45,000
	Bovine serum albumin	66,200
	Phosphorylase B (rabbit muscle)	97,400;

15 which factor has mitogenic activity stimulating the division of rat Schwann cells in the presence of foetal calf plasma, and when isolated using reversed-phase HPLC retains at least 50% of said activity after 10 weeks incubation in 0.1% trifluoroacetic acid at 4°C.

2. A basic polypeptide factor having an observed molecular weight, under non-reducing conditions, of from 55 kD to 63 kD on SDS-polyacrylamide gel electrophoresis using the following molecular weight standards:

	Lysozyme (hen egg white)	14,400
	Soybean trypsin inhibitor	21,500
	Carbonic anhydrase (bovine)	31,000
30	Ovalbumin (hen egg white)	45,000
	Bovine serum albumin	66,200
	Phosphorylase B (rabbit muscle)	97,400;

35 which factor has mitogenic activity stimulating the division of rat Schwann cells in the presence of foetal



calf plasma, and when isolated using reversed-phase HPLC retains at least about 50% of said activity after 4 days incubation in 0.1% trifluoroacetic acid at 4°C.

- 05 3. A process for the preparation of a polypeptide defined  
in Claim 1 or Claim 2, comprising extracting vertebrate  
brain material to obtain protein, subjecting the resulting  
extract to chromatographic purification comprising  
hydroxylapatite HPLC and thereafter to SDS-polyacrylamide  
10 gel electrophoresis and collecting that fraction therefrom  
which has an observed molecular weight of about 30 kD to 36  
kD and/or that fraction which has an observed molecular  
weight of about 55 kD to 63 kD if, in either case,  
subjected to SDS-polyacrylamide gel electrophoresis using  
15 the following molecular weight standards:

	Lysozyme (hen egg white)	14,400
	Soybean trypsin inhibitor	21,500
	Carbonic anhydrase (bovine)	31,000
20	Ovalbumin (hen egg white)	45,000
	Bovine serum albumin	66,200
	Phosphorylase B (rabbit muscle)	97,400;

- 25 in the case of the aforesaid smaller molecular weight  
fraction whether in reducing conditions or not, and in the  
case of the aforesaid larger molecular weight fraction,  
under non-reducing conditions, and which fraction(s)  
exhibit(s) mitogenic activity stimulating the division of  
rat Schwann cells against a background of foetal calf  
30 plasma.

4. A process as claimed in Claim 3, wherein the brain  
material is pituitary material.

- 35 5. A process as claimed in Claim 4, wherein the source of

pituitary material is bovine.

05 6. A process as claimed in any one of Claims 3 to 5,  
wherein the protein initially extracted from brain material  
is first subjected to carboxymethyl cellulose  
chromatography.

10 7. A process as claimed in any one of Claims 3 to 6 also  
including, after hydroxylapatite HPLC, cation exchange  
chromatography, gel filtration, and/or reversed-phase HPLC.

8. A process as claimed in Claim 7, wherein reversed-  
phase HPLC is employed using trifluoroacetic acid as an ion  
pairing agent.

15 9. A process as claimed in any one of Claims 3 to 8,  
wherein at each stage biological activity of material  
obtained is assessed as the level of mitogenic activity  
stimulating the division of rat Schwann cells against a  
20 background of foetal calf plasma.

10. A process for preparing a polypeptide defined in Claim  
1 or Claim 2 and in which at least one step is  
substantially as hereinbefore described in the foregoing  
25 Example.

11. An assay for glial cell mitogenic activity in which a  
background of foetal calf plasma is employed against which  
to assess DNA synthesis in glial cells stimulated (if at  
30 all) by a substance under assay.

12. An assay as claimed in Claim 11, wherein the glial  
cells are Schwann cells.

35 13. An assay as defined in Claim 11 and substantially as

hereinbefore described.

14. A pharmaceutical or veterinary formulation comprising a polypeptide as claimed in Claim 1 or Claim 2 formulated  
05 for pharmaceutical or veterinary use, respectively, optionally together with an acceptable diluent, carrier or excipient and/or in unit dosage form.

15. The use of a polypeptide defined in Claim 1 or Claim  
10 2 as a glial cell mitogen in vivo or in vitro.

16. A polypeptide as claimed in Claim 1 or Claim 2 for use as a glial cell mitogen.

17. A method for producing a glial cell mitogenic effect in a vertebrate by administering an effective amount of a polypeptide defined in Claim 1 or Claim 2.

18. A method as claimed in Claim 17 when used in the  
20 treatment or prophylaxis of a nervous disease or disorder.

19. A method for the prophylaxis or treatment of pathophysiological condition of the nervous system in which a cell type is involved which is sensitive or responsive to  
25 a polypeptide as defined in Claim 1 or Claim 2 comprising administering an effective amount of said polypeptide.

20. A method as claimed in Claim 19, wherein the condition involves peripheral nerve damage.

21. A method for the prophylaxis or treatment of a condition which involves demyelination or damage or loss of Schwann cells, for example a neuropathy of sensory or motor nerve fibres, which comprises administering an effective  
35 amount of a polypeptide as defined in Claim 1 or Claim 2.

22. The use of a polypeptide as defined in Claim 1 or Claim 2 in the manufacture of a medicament.

05 23. The use of a polypeptide as defined in Claim 1 or Claim 2 as an immunogen to generate antibodies, optionally said antibodies being for diagnostic purposes.

10 24. The use of a polypeptide as defined in Claim 1 or Claim 2 in a competitive assay to identify or quantify molecules having receptor binding characteristics corresponding to those of said polypeptide.

15 25. The use of claim 24, wherein said polypeptide is labeled, optionally with a radioisotope.

20 26. The use of a polypeptide as defined in Claim 1 or Claim 2 in an affinity isolation process, optionally affinity chromatography, for the separation of a corresponding receptor.

25 27. A method for the prophylaxis or treatment of a glial tumour, which comprises administering an effective amount of a substance which inhibits the binding of a factor as defined in Claim 1 or Claim 2 to a receptor therefor.

30

35

Figure 1 to accompany abstract

- 25 -

ABSTRACT

Glial Mitogenic Factors, Their Preparation and Use

05       The invention provides new Schwann cell-mitogenic  
factors of molecular weight 30 to 36 and 55 to 63  
kilodaltons, respectively, when isolated by SDS-PAGE. The  
invention provides therapeutic formulations comprising the  
new factors, and the use of the factors and those  
10       formulations in treating conditions which involve a factor-  
sensitive or factor-responsive cell type.

15

20

25

30

35

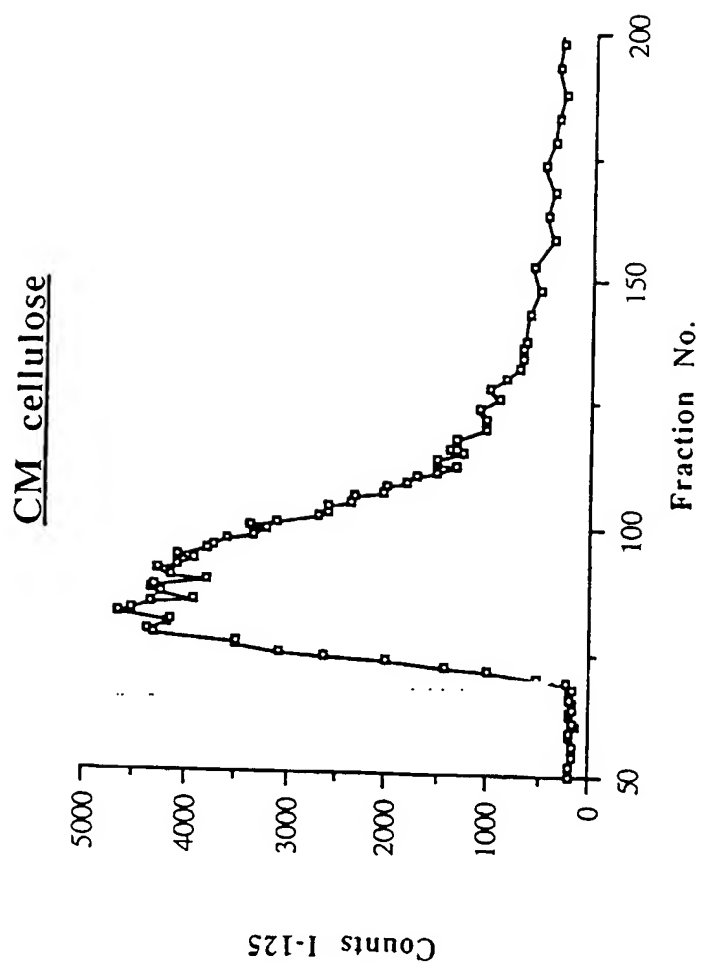


FIGURE 1

# Hydroxylapatite HPLC

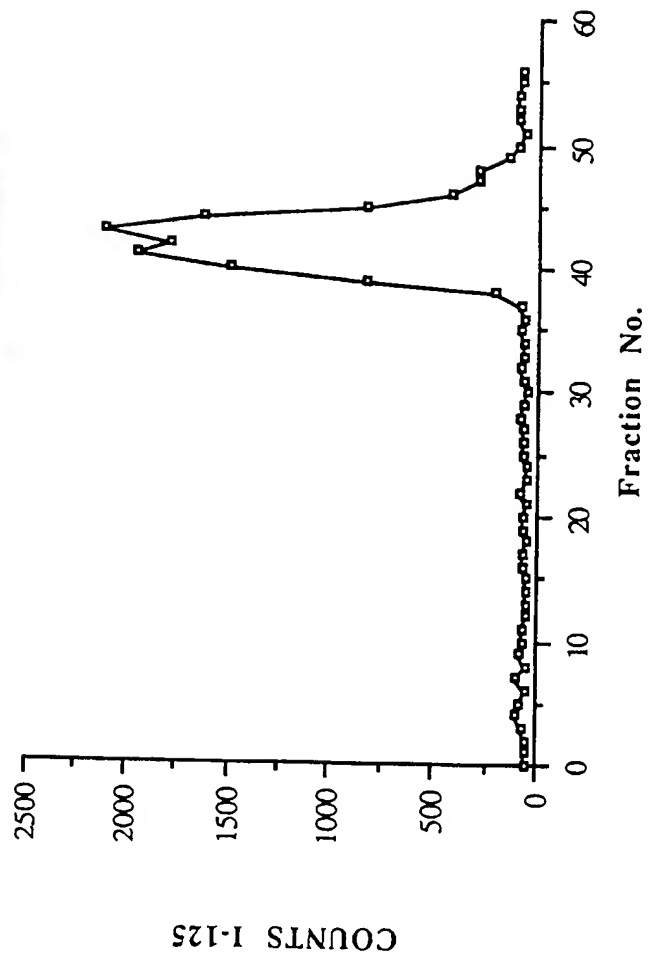


FIGURE 2

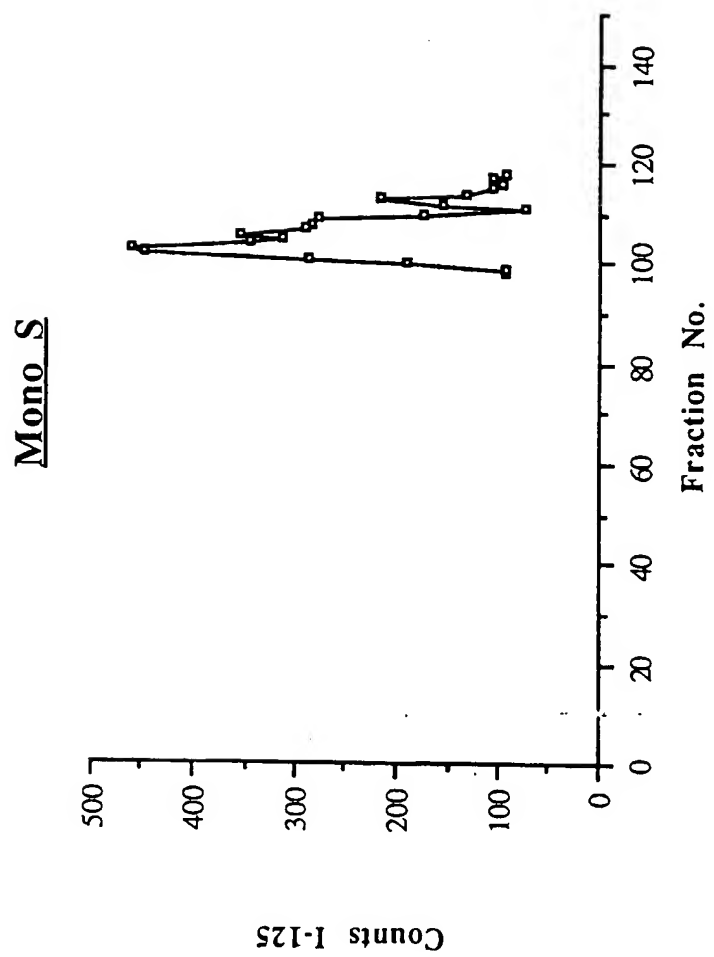


FIGURE 3



Superose 12 gel filtration FPLC

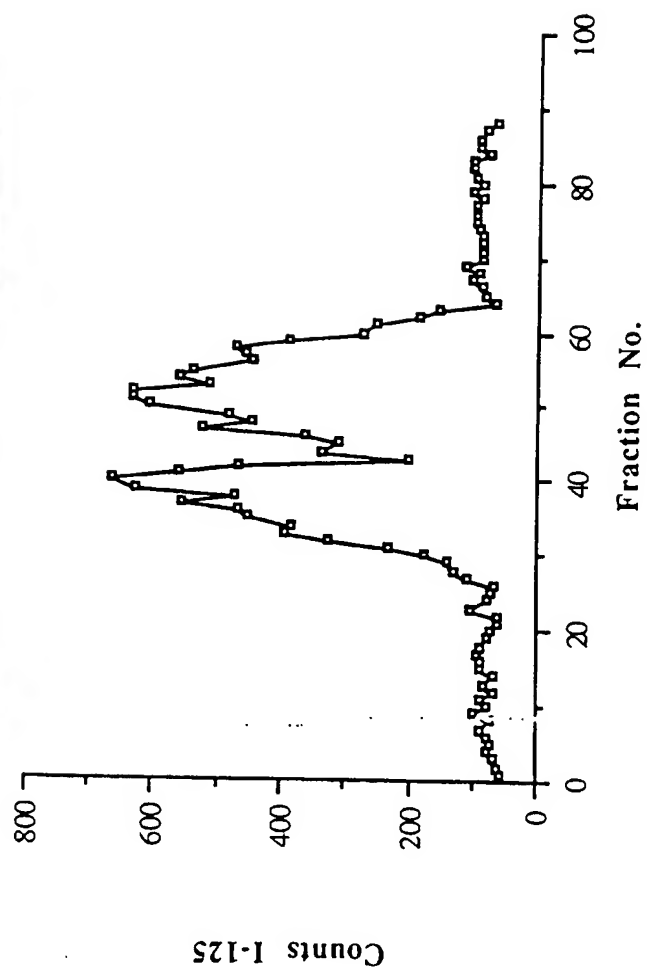


FIGURE 4

Reversed phase HPLC

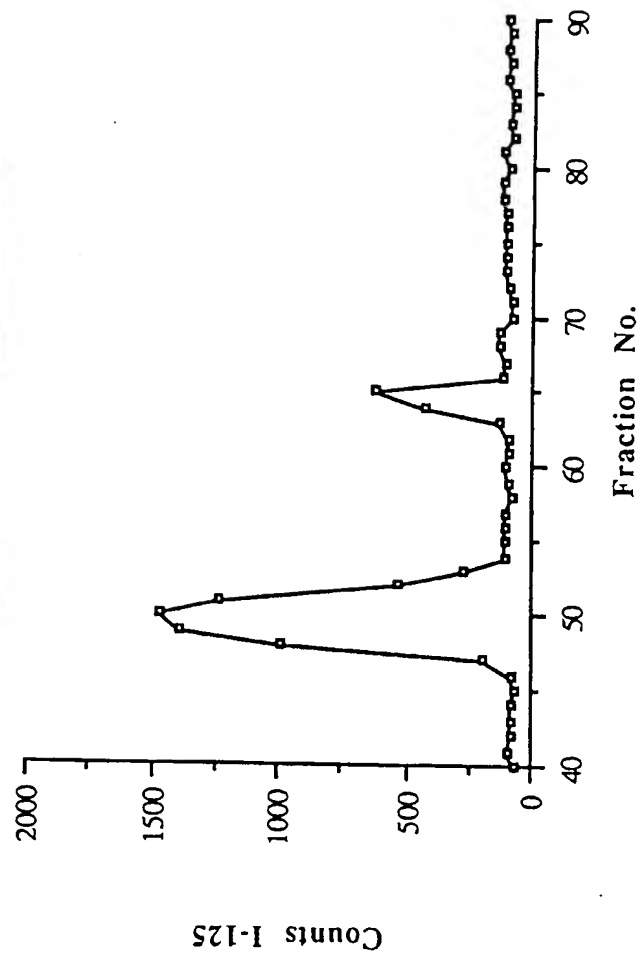


FIGURE 5

Reversed phase HPLC

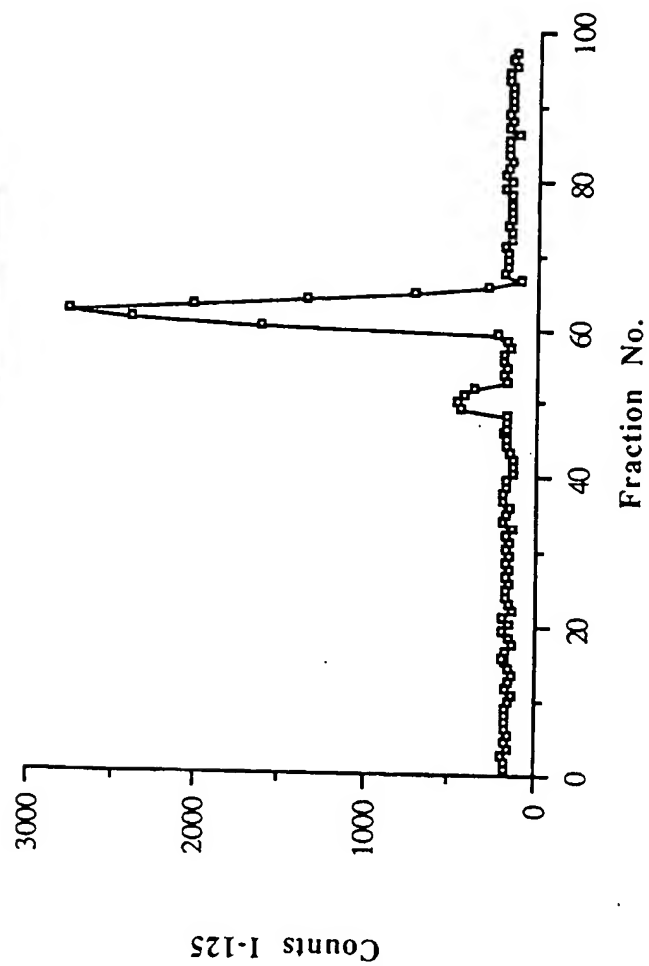


FIGURE 6

Factor-I dose response in serum & plasma

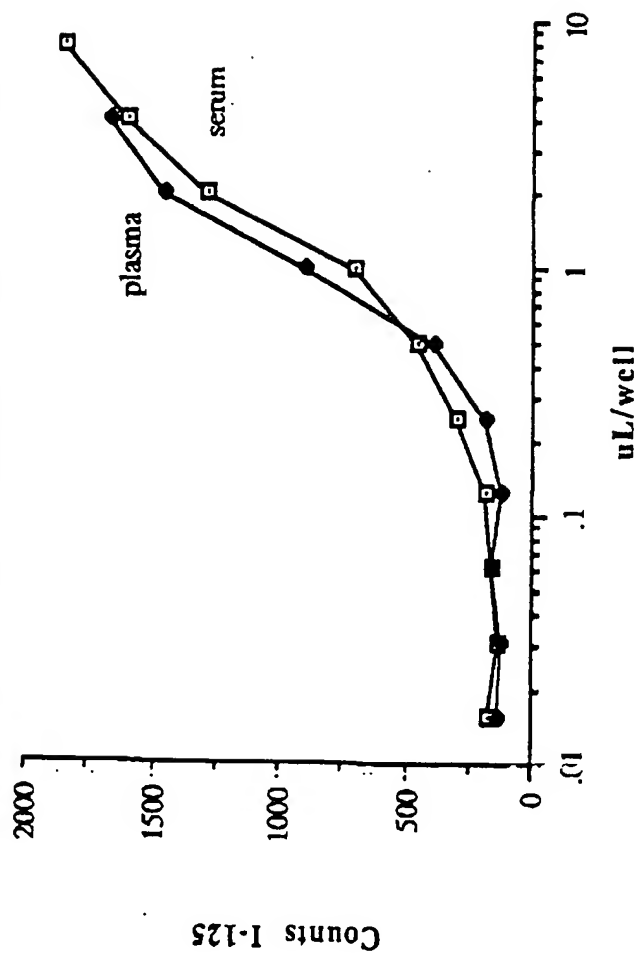


FIGURE 7

Factor-II dose response in serum or plasma

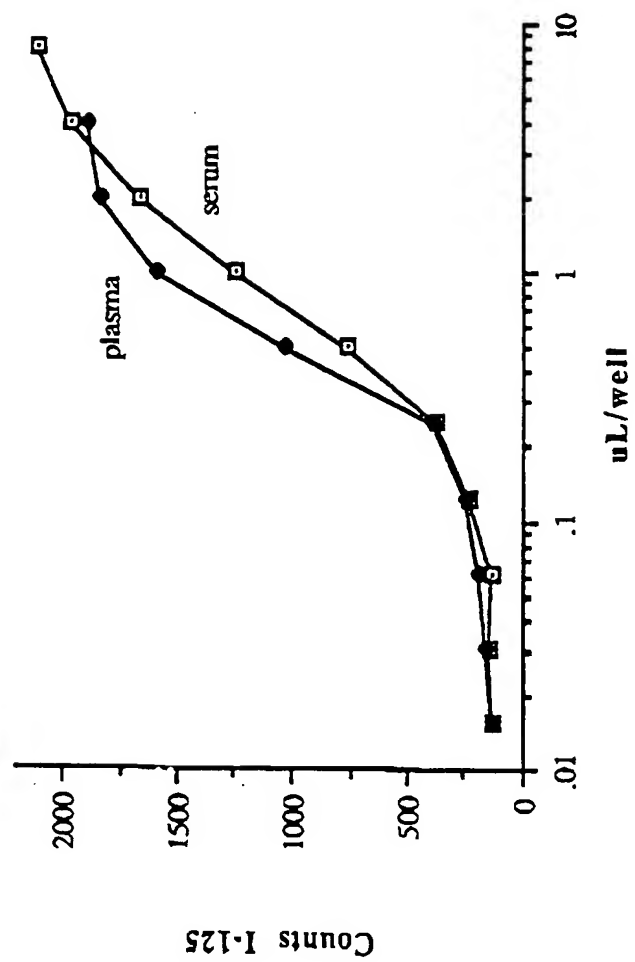


FIGURE 8

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**